

**U.S. GEOLOGICAL SURVEY**

**RESEARCH/DEVELOPMENT SCIENTIST RECORD**

Research Grade Evaluation (RGE) review

**1. NAME:** Gregory J. McCabe

**2. DATE PREPARED:** February, 2011

**3. DUTY STATION:** National Research Program, Denver, Colorado

**4. REGION:** Central/Surface Water Hydrology

**5. CLASSIFICATION TITLE, SERIES, AND GRADE:** Physical Scientist, GS-1301-15

**6. DATE OF ENTRANCE ON DUTY:** September, 1988

**7. DATE OF LAST PROMOTION:** July, 2002

**8. DATE OF LAST RESEARCH GRADE PANEL REVIEW:** Spring, 2010

**9. EDUCATION:**

Louisiana State University (8/1983-8/1986): MAJOR: Climatology and Physical Geography  
MINOR: Agricultural Engineering  
Ph.D. (1986)

University of Delaware (9/1980-8/1983): MAJOR: Climatology and Physical Geography  
M.A. (1984)

University of Delaware (9/1974-6/1980): MAJOR: Climatology and Physical Geography  
BA (1980)

**10. TECHNICAL TRAINING RECEIVED:**

ARC/INFO, 1990

**11. PROFESSIONAL EXPERIENCE:**

**a. PRESENT ASSIGNMENT:**

**DATES:** From: 10/2001 To: present

PROJECT TITLE: Hydro-climatic Processes and Hazards

DATES OF PROJECT: 10/2001 to present

SOURCE OF FUNDING: NRP

PROJECT CHIEF: Greg McCabe

PROBLEM: Climate displays an often unrecognized order in both time and space. What may appear as a random sequence of precipitation at a point or within a watershed is actually the local expression of a broad

integrated system of weather processes that are active on scales of 100's to 1000's of kilometers. Only when climate forcings and hydrologic responses are considered from a regional perspective does the order become evident. Understanding these regional processes provides a sound basis for national, regional, and local hydrologic analysis, resource management, and hazard assessment/mitigation.

**OBJECTIVES:** (1) to identify and quantify relations between large-scale atmospheric circulation and surface hydrologic variables (e.g. precipitation, snow, streamflow), (2) development of improved precipitation-runoff models, and (3) examination of the effects of climatic variability and change on water resources.

**APPROACH:** The general approach is to develop and use conceptual and empirical models that characterize the relations between atmospheric/oceanic conditions and surface hydrologic processes. For example, statistical models are used to study relations between North Pacific Ocean climate processes and hydroclimatic variables in the United States. Conceptual hydrologic models are used to describe and explain the spatial and temporal variability of the water balance. The understanding of the hydro-climate gained from these modeling studies provides a base of knowledge of the relations between climatic and hydrologic variables that improves hydrologic prediction and water resources management.

I also am serving as an adjunct professor in the Department of Earth and Atmospheric Sciences at Metropolitan State College of Denver and in the Department of Geography at the University of Denver. In addition I am a research affiliate with the Institute of Arctic and Alpine Research at the University of Colorado.

#### **b. PREVIOUS PROFESSIONAL POSITIONS:**

**DATES:**        From: 8/1991                                To: 10/2001

Physical Scientist, Precipitation-Runoff Modeling Project, NRP, Denver, Colorado, researched relations between large-scale atmospheric circulation and surface hydrologic processes, as well as the hydrologic effects of climate change. I also served as an adjunct professor in the Department of Earth and Atmospheric Sciences at Metropolitan State College of Denver.

**DATES:**        From: 1/1991                                To: 8/1991

Project Chief of the Delaware River Basin Climate Change Project, New Jersey Water Science Center, responsible for research of the effects of climate change on water resources in the Delaware River Basin and the coordination of research efforts by project members. I also served as an adjunct professor in the Department of Agronomy and Environmental Science at Delaware Valley College.

**DATES:**        From: 9/1988                                To: 1/1991

Physical Scientist, New Jersey Water Science Center, studied the effects of potential climate change on the water resources of the Delaware River Basin. I also worked as an adjunct professor in the Department of Geologic and Marine Sciences at Rider College and in the Department of Agronomy and Environmental Science at Delaware Valley College.

**DATES:**        From: 8/1986                                To: 9/1988

Assistant Professor, Department of Geography and Planning, University of Memphis, responsible for climatology and meteorology courses and hydroclimatological research. I also served on several departmental and university committees.

## 12. SIGNIFICANT RESEARCH ACCOMPLISHMENTS:

### a. RECENT ACCOMPLISHMENTS:

#### **Associations Between Decadal to Multidecadal Sea-Surface Temperature Variability and Hydroclimate of the U.S.**

**Background:** I have been working with a number of government, university, and private sector scientists to identify linkages between low frequency (decadal to multidecadal (D2M)) variability of sea-surface temperatures (SSTs) and the hydroclimate of the U.S. This work began with a study of the relations between drought occurrence and global sea-surface temperatures (SSTs) (McCabe et al, 2004; McCabe et al., 2008).

**Role:** I contributed to the planning of the research approaches, designed and performed analyses, coordinated research efforts by co-authors, wrote journal articles, made many presentations.

**Results:** This research indicated that a significant amount of the variability in D2M drought frequency in the U.S. is associated with SST variability in both the Pacific and Atlantic Oceans. This work was expanded to include analyses of global D2M climate variability (McCabe and Palecki, 2006; Apipattanavis et al., 2009) and analyses of important river basins such as the Colorado River basin (McCabe et al., 2007; Gangopadhyay and McCabe, 2010). Results from our analyses of observational data have been supported by recent climate modeling studies and by paleoclimate studies. This research shows that a significant amount of the D2M variability in U.S. climate is associated with D2M SST variability in both the Pacific and Atlantic Oceans. Results also indicate that on D2M temporal scales, North Atlantic SSTs may be as important as are Pacific SSTs.

**Impact:** This result initiated a lively discussion among a number of climate scientists and has raised a number of questions regarding the importance of North Atlantic climate variability. My co-authors and I have been invited to present a large number of talks on this topic (over 60). Some of the implications of the research are that (1) on D2M temporal scales, since variability of North Atlantic SSTs appears to be as important as is the D2M variability of Pacific Ocean SSTs, more research is needed on North Atlantic Ocean climate influences, (2) increased understanding of the D2M climate variability may prove useful to improve climatic and hydrologic forecasts and water resource management, and (3) increased understanding of D2M climatic variability should lead to improvements in global climate models. (This research was mentioned in an article in *Time* magazine, and was included in the most recent IPCC report. In addition, this research was the basis for an invitation to participate in a USGS podcast, was the subject of a National FOX NEWS story, and was part of a documentary for the *National Geographic Channel*.)

#### **Hydrologic Effects of Climate Variability and Change**

**Background:** Analyses of the hydrologic effects of climate change have included analyses of the effects of climate change on (1) snowpack accumulations in the western United States (McCabe and Wolock, 1999; McCabe and Wolock, 2009), (2) annual runoff (Wolock and McCabe, 1999; Hay and McCabe, 2010), (3) global snow cover (McCabe and Wolock, 2010), (4) global runoff (McCabe and Wolock, 2008; McCabe and Wolock, 2010), (5) streamflow timing (McCabe and Clark, 2005), and (6) water supply of the Colorado River (McCabe and Wolock, 2007).

**Role:** I planned research approaches, designed and performed analyses, coordinated research efforts by co-authors, wrote journal articles, and made presentations of project results.

**Results:** These studies have shown associations between increased temperatures in the western US and decreases in snowpack accumulations, decreases in rain-on-snow events, and decreases in streamflow the western U.S. In addition, results indicate that around 1984 there was an abrupt shift to earlier snowmelt runoff in the western US. This shift in snowmelt runoff appears to be related to an abrupt increase in atmospheric pressures over the western U.S. and temperature during the spring and early summer seasons. More recent research has involved examination of the hydrologic effects of warming on the water supply of the Colorado River Basin. Results of this research indicate that small increases in temperature, with no compensating increases in precipitation, could result in substantial water shortages in the Colorado River Basin and more than double the risk of failing to meet the obligations of the Colorado Compact.

**Impact:** The results of the earliest research products were included in the final reports to Congress of the U.S. National Assessment of the Effects of Climate Change and were used by other sectors of the National Assessment such as Coastal Resources, Forestry, and Agriculture. The recent research of hydrologic effects of warming on the Colorado River Basin provides important information for water managers to consider when developing management strategies for the Colorado River Basin. Findings of this research were mentioned in a "Search and Discovery" article in *Physics Today* (April 2008) on climate change, also resulted in a press conference with USGS Director Mark Myers in April 2008 and was the focus of a congressional briefing in June 2008. In addition this research was featured in a story published in *Scientific American*

(December 9, 2008). Recently both the Secretary of Interior and the Assistant Secretary of Interior have requested information from this research for talks they presented.

### **Trends in Hydrologic Conditions**

**Background:** Climate model simulations using enhanced greenhouse forcing generally indicate widespread increases in precipitation and runoff, an outcome frequently cited as representing an intensified or accelerated hydrologic cycle. The importance of an intensified hydrologic cycle stems from the possibility that it could lead to an increase in extreme hydrologic events, such as floods. Dave Wolock (USGS, Kansas) and I performed analyses to clarify the nature of temporal changes in streamflow in the conterminous U.S. during the latter half of the twentieth century (McCabe and Wolock, 2002). More recently I performed additional research on this topic (with David Legates, University of Delaware) and Harry Lins (USGS, OSW, Reston) examining trends in drought frequency and duration in the southwestern U.S (McCabe et al., 2010). Current research with Dave Wolock addresses variability and trends in runoff in the conterminous U.S. during the 20<sup>th</sup> century.

**Role:** I planned research approaches, performed analyses, coordinated research efforts by co-authors, wrote journal articles, and made presentations of project results.

**Results:** Results indicated that (1) there are relatively few sites with significant changes in annual maximum daily streamflow as compared to annual minimum and median daily streamflow; (2) most changes in streamflow statistics appear as increases in annual minimum and median daily streamflow in the eastern U.S; and (4) all of the increases in annual streamflow statistics appear to have been the result of a step increase around 1970 rather than as a gradual trend. The more recent work on drought frequency and drought duration in the southwestern U.S. indicated decreases in both drought frequency and drought duration over the past 60 years. The decreases in drought frequency and drought duration are associated with an increase in El Nino events. This research increases the understanding of recent climate trends in the southwestern U.S. amid global warming.

**Impact:** The interpretation of a step change is that the climate system has shifted to a new regime that will likely remain relatively constant until a new shift or step change occurs. The streamflow trends study was selected for *Journal Highlights* by EOS. The research of hydrologic trends increases the understanding of recent climate trends in the U.S. amid global warming.

### **Variability in Snow Cover and Depth**

**Background:** Two recent analyses of the long-term variability in snow water equivalent (SWE) and snow covered area were completed (McCabe and Wolock, 2009; 2010). One study was an analysis of 20<sup>th</sup> century variability in western U.S. snow water equivalent and the other was an analysis of the variability of 20<sup>th</sup> century Northern Hemisphere snow cover.

**Role:** I planned research approaches, performed analyses, wrote journal articles, and made presentations of project results.

**Results:** Results showed that post-1980 lower-than-average snowpack conditions in the western U.S. are unprecedented within the context of twentieth century temporal variability in precipitation, temperature, and estimated SWE (McCabe and Wolock, 2009). During the most recent two decades, winter temperatures have been higher, on average, than any other decades during the twentieth century. Associated with the higher temperatures, decadal averages of April 1 SWE and the SWE/precipitation ratio have been lower than any other decades dating back to 1900. The continued decline of April 1 SWE will assuredly have important implications for water management in the western U.S. The second study involved an analysis of the variability of 20<sup>th</sup> century Northern Hemisphere snow cover (McCabe and Wolock, 2010). Analyses indicated that Northern Hemisphere March snow covered area (SCA) substantially decreased since about 1970, and this decrease corresponds to an increase in mean winter Northern Hemisphere temperature. The increase in winter temperature has caused a decrease in the fraction of precipitation that occurs as snow and an increase in snowmelt for some parts of the Northern Hemisphere, particularly the mid-latitudes, thus reducing snow packs and SCA. In addition, the increase in winter temperature and the decreases in SCA appear to be associated with a contraction of the circumpolar vortex and a poleward movement of storm tracks, resulting in decreased precipitation (and snow) in the low- to mid-latitudes and an increase in precipitation (and snow) in high latitudes.

**Impact:** The significance of these studies is that they address an important integrator of climate (i.e. snowpacks and snow cover). The analyses put recent changes in snow conditions in the context of 20<sup>th</sup> century climate variability and also provide an explanation for recent declines in both snow water equivalent in the western U.S. and Northern Hemisphere snow cover. The results of these studies have important implications for understanding the effects of global warming and for understanding the effects of current and future climate on water resources.

## **b. OTHER CAREER ACCOMPLISHMENTS:**

### **Teleconnections and the Hydroclimate of the U.S.**

**Background:** For a number of years I have been involved with studies to identify and quantify relations between variability in atmospheric circulation and sea-surface temperatures and temporal and spatial variability of hydroclimatic variables (e.g. precipitation, snowpack, streamflow) in the U.S. (e.g. McCabe, 1994; McCabe et.al., 1994; McCabe and Legates, 1995; McCabe, 1995; Dettinger et al., 1999; McCabe and Dettinger, 1999; Clark et al., 2001; Dettinger et al., 2001; McCabe and Dettinger, 2002; McCabe and Muller, 2002; McCabe et al., 2004; Hay et al., 2009).

**Role:** I planned research approaches, designed and performed analyses, coordinated research efforts by co-authors, wrote journal articles, and made presentations of project results.

**Results:** These studies show linkages between U.S. surface hydroclimate and variability in atmospheric circulation and sea-surface temperatures. For example, the effects of the El Nino Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO) have been clarified through these research efforts. One paper identified the interactions between ENSO and PDO and the resultant effects on western US precipitation (McCabe and Dettinger, 1999). This paper has been cited by over 200 other papers. Another paper addressed the effects of ENSO and the PDO on snowpack in the western U.S. This paper has been cited by about 100 other papers.

**Impact:** This research has (1) helped explain physical connections between atmospheric circulation and variability in water resources in the U.S., (2) identified the effects of interactions between high and low frequency climate variability on hydroclimatic variables, and (3) important implications for the development of models for long-range (3 to 6 month) forecasts of hydroclimatic conditions in the U.S.

### **Hydrologic Modeling**

**Background:** An understanding of the factors that control components of the annual water balance provides a base of knowledge of the relations between climatic and hydrologic variables. Dave Wolock (USGS, Kansas) and I performed analyses to determine which hydrologic concepts are needed in a water-balance model to estimate the spatial variation in mean annual runoff in the conterminous U.S. (Wolock and McCabe, 1999). This study was motivated by the need to test continental-scale hydrologic models, such as those used in atmospheric general circulation models.

**Role:** I planned research approaches, designed and performed analyses, coordinated research efforts by co-authors, wrote journal articles, and made presentations of project results.

**Results:** Most (91 percent) of the spatial variability in mean annual runoff in the conterminous U.S. was explained by the spatial variability of mean annual precipitation minus mean annual potential evapotranspiration. When soil-moisture-storage capacity and seasonality in precipitation (P) and potential evapotranspiration (PE) were added to the water balance, the explained variance in mean annual runoff increased slightly, and the error in estimated mean annual runoff decreased significantly. Adding soil-moisture-storage capacity and seasonality in P and PE provided the most improvement in areas where seasonal P and PE are out of phase.

**Impact:** This research added insight to the factors that control the annual water balance and also provided the foundation for a water-balance model that was used by a number of researchers involved with the U.S. National Assessment of the Potential Consequences of Climate Variability and Change.

### **Detection of Hydrologic Trends**

**Background:** Many studies of the hydrologic effects of climate change only examine changes in mean hydrologic conditions and do not examine these changes amid natural hydrologic variability. With Dave Wolock (USGS, Kansas) I performed analyses to determine the effects of natural hydrologic variability on the detection of long-term trends in U.S. runoff (McCabe and Wolock, 1997).

**Role:** I planned research approaches, designed and performed analyses, coordinated research efforts by co-authors, wrote journal articles, and made presentations of project results.

**Results:** Natural hydrologic variability is large enough in many locations of the conterminous United States to mask the effects of changes in mean annual runoff that result from climate change.

**Impact:** This research illustrates the large effect of natural variability on the detection of hydrologic trends. Even if substantial changes in mean annual runoff occur, they are unlikely to be detected in time series of mean annual runoff. Statistical analyses of runoff data, therefore, will not indicate trends even when real changes in runoff are occurring. The results of this paper were used by other researchers to help reconcile differences among studies that have examined the existence of trends in hydrologic variables.

### **Delaware River Basin Climate Change Study**

**Background:** Many significant research contributions were a result of the USGS Delaware River Basin climate change project (1988-1991). The primary objectives of the project were to (1) identify problems and uncertainties associated with the detection and prediction of climate change, (2) examine the reliability of general-circulation-model simulations, and (3) describe the hydrologic sensitivities of the Delaware River Basin to climate change.

**Role:** I planned research approaches, designed and performed analyses, coordinated research efforts by co-authors, wrote journal articles, and made presentations of project results.

**Results:** Two of the important products from this project were a (1) stochastic precipitation model, and (2) monthly water balance model of the Delaware River Basin that included reservoir management practices that are used to control flow levels in the river and to control the position of the salt front in the Delaware Estuary.

**Impact:** The models were used with various scenarios of future climatic conditions to examine the hydrologic effects of climate change in the Delaware River Basin. Some of the research also was expanded to include the entire conterminous U.S. As a member of this project I authored or co-authored 28 journal and proceedings papers.

### **Changes in Glacier Mass Balance**

**Background:** Glaciers are good integrators of climatic variability and changes. I have worked on several studies to understand trends and variability in glacier mass balance (McCabe and Fountain, 1995; McCabe et al, 2000; Meier et al, 2003; Dyurgerov and McCabe, 2006). Current research with Andrew Fountain (Portland State University) is addressing the independent effects of temperature and precipitation on glacier mass balance during the 20<sup>th</sup> century.

**Role:** I planned research approaches, designed and performed analyses, coordinated research efforts by co-authors, wrote journal articles, and made presentations of project results.

**Results:** Losses of glacier mass appear to be related to an abrupt increase in summer temperatures during the late 1980s and early 1900s for many regions of the globe. These losses in glacier mass balance are related to an increase in sea-level and suggest that the acceleration in wastage of mountain glaciers and subpolar ice caps in coastal areas may be an early warning of larger changes in Greenland and West Antarctic ice sheets.

**Impact:** These studies clarified trends in glacier mass balance and provided explanations of the climatic factors driving these trends.

### **Development of a Stochastic Weather-Type Based Precipitation Model**

**Background:** With Lauren Hay (USGS, Denver) and David Wolock (USGS, Kansas) I helped develop a weather-type based stochastic precipitation model (Hay et.al., 1991; Hay et.al., 1992).

**Role:** I planned research approaches, designed and performed analyses, wrote journal articles, and made presentations of project results.

**Results:** The model was based on statistics of weather type occurrence and weather-type precipitation statistics. This model was applied to the Delaware River Basin and the statistics describing simulated average precipitation, extreme precipitation, and drought conditions closely matched those of the observed data. A similar model was later developed to model daily temperatures, and both models were used with general-circulation-model estimates of future atmospheric circulation to develop climate change scenarios for the Delaware River Basin.

**Impact:** The methodology used to develop this model received a great deal of attention from precipitation modelers in the United States and in foreign countries, particularly Germany and Japan. The methodology has been used by a number of researchers as a framework for the development of similar stochastic precipitation/temperature models.

### **Development of the USGS National Daily Streamflow Conditions Web Page**

**Background:** With Dave Wolock (USGS, Kansas) and Harry Lins (OSW) I helped develop the prototype of the USGS daily hydrologic conditions web page.

**Role:** I helped coordinate the efforts to compile the computer programs needed to access the streamflow data and streamflow statistics and to plot these data as a map on a USGS web page.

**Results:** This page provides current streamflow data in the context of historical values. It also provides current and historical daily values of streamflow via an interactive map.

**Impact:** This web page provided the first national view of current streamflow conditions to the public. Since its development this page has been one of the most widely visited USGS web pages. I received a USGS Star Award for my participation on this project. (see <http://waterwatch.usgs.gov/new>)

### 13. SCIENTIFIC LEADERSHIP

I provide scientific leadership in the field of hydroclimatology and climate-change research. This leadership is evidenced in several ways:

I have been invited and served on a number of USGS and other agency committees to address issues related to hydroclimatology and climate change (see sections 14c through 14g for details) and I have provided expertise in hydroclimatology to the USGS, other government agencies, and universities. For example, I have worked with colleagues from the National Weather Service, the Army Corps of Engineers, the Earth Systems Research Laboratory, the Bureau of Reclamation, the Western Area Power Administration, the Illinois State Water Survey, the National Climatic Data center, the University of Delaware, Arizona State University, the University of Arizona, the University of Colorado, Scripps Institution of Oceanography, Louisiana State University, Montana State University, University of Pennsylvania, Portland State University, University of Wyoming, and the University of Washington. Within the USGS I have worked with Water Science Center scientists on various projects related to hydroclimatic and climatic-change research. Specifically I have worked with scientists from the New Jersey, Kansas, California, Alaska, Oregon, North Dakota, Alabama, and Colorado Water Science Centers. In addition, I have given many lectures at USGS Water Science Centers.

In addition to consultation and collaboration with US agencies and universities I also have provided expertise to foreign agencies such as the Public Works Research Institute of Japan and the Japanese Science and Technology Agency. For example, I collaborated with Japanese scientists on climate change research and on the development of a weather-type based stochastic precipitation model for hydrologic studies in Japan. Recently I helped scientists in Hungary apply a water balance model to examine water resource issues in that country and a version of this model is being used as a starting point for a lake model for the Nile River basin in Egypt.

I also provide scientific judgment to government agencies and professional organizations through reviews of grant proposals and journal publications. I served as an associate editor for the *Journal of Hydrologic Engineering* for several years and have been a reviewer of manuscripts for many scientific journals (see sections 14c).

My research has been recognized nationally and internationally and I have been invited to make many presentations at scientific meetings and universities, and have been invited to write a number of journal papers and book chapters (see sections 14b, 14d, and 18a).

In addition to scientific consultation and serving as a scientific reviewer I also have provided leadership in the development of climate data sets and climate-research methodologies needed in hydroclimatic research. These data sets have been shared with USGS scientists as well as with other government and university scientists (see section 15 for some examples). With Dave Wolock I helped develop the prototype of what has become the USGS WaterWatch web page, which is one of the most viewed USGS web pages.

Within the USGS I served as Research Advisor for the Surface Water discipline in the NRP during 2003-2005 and as Assistant Research Advisor from 2000-2002. I also have been serving as a member of the World Meteorological Organization (WMO) Commission for Hydrology (2005-present), as a member of the writing team for the WaterSmart Colorado River Basin focus area, and as a member of the Strategic Science Planning Team for Water.

In addition to my research activities I have maintained connections with local universities and have taught courses and mentored students. Currently I am an adjunct professor in the Department of Earth and Atmospheric Sciences at Metropolitan State College of Denver, and in the Department of Geography at the University of

Denver. I also am a research affiliate with the Institute of Arctic and Alpine Research at the University of Colorado.

#### **14. SCIENTIFIC AND PUBLIC SERVICE:**

##### **a. CURRENT MEMBERSHIPS IN PROFESSIONAL SOCIETIES:**

American Geophysical Union

International Association of Hydrological Science

Technical Program Committee, annual conference of the American Water Resources Association, “Water Management of River Systems”, New Orleans, Louisiana, 1991.

Technical Program Committee, American Water Resources Association, Annual Summer Symposium, “Water Resources and Environmental Hazards: Emphasis on Hydrologic and Cultural Insight in the Pacific Rim”, Honolulu, Hawaii, June, 1995.

Chaired and/or organized various sessions for annual meetings of the Association of American Geographers, American Society of Civil Engineers, and the American Water Resources Association.

##### **b. TECHNICAL PRESENTATIONS: (115 of the following presentations were invited)**

1. McCabe, G.J., **Relationship of Synoptic Weather Types to Excessive Precipitation in Louisiana**, Annual Meeting of the Association of American Geographers, Detroit, Michigan, April, 1985. (PRESENTED, INVITED)
2. Faiers, G.E. and G.J. McCabe, **Cloud Enhancement Over an Industrial Site in Baton Rouge**, Louisiana, Annual Meeting of the Southeastern Division of the Association of American Geographers, Chapel Hill, North Carolina, November, 1985.
3. Bengtson, R.L., J.L. Fouss and G.J. McCabe, **Effects of Evapotranspiration on Modeling in Southern Louisiana**, American Society of Agricultural Engineering, Semi-Annual Meeting, Chicago, Illinois, December, 1985.
4. McCabe, G.J., **Use of Synoptic Weather Types in the Analysis of Evaporation**, Annual Meeting of the Association of American Geographers, Annual Meeting, Minneapolis, Minnesota, May, 1986. (PRESENTED)
5. McCabe, G.J., **Synoptic Weather Types: An Index of Evaporation in Southern Louisiana**, Annual Meeting of the Southeastern Division of the Association of American Geographers, Lexington, Kentucky, November, 1986. (PRESENTED)
6. McCabe, G.J., **Commentary on ‘Well Level Fluctuations as a Calibration Device for Estimated Recharge’ by Jacqueline Pryce-Harvey**, Annual Meeting of the Southeastern Division of the Association of American Geographers, Lexington, Kentucky, 1986. (PRESENTED, INVITED)



7. McCabe, G.J., **Synoptic Weather Types: An Index of Evaporation**, Annual Meeting of the Association of American Geographers, Portland, Oregon, April, 1987. (PRESENTED)
8. McCabe, G.J., **Applications of Synoptic Weather Types and Water Budget Analysis**, Meeting of the Memphis Chapter of the American Meteorological Society, Memphis, Tennessee, September, 1987. (PRESENTED, INVITED)
9. McCabe, G.J., **Temperature Trends in Tennessee**, Annual Meeting of the Tennessee Academy of Science, Jackson, Tennessee, November, 1987. (PRESENTED)
10. Barnhardt, M.L. and G.J. McCabe, **Erosion in Reclaimed and Natural Gullies: Monitoring the Water and Sediment Budgets**, Annual Meeting of the American Society of Agronomy/Soil Science Society of America, Atlanta, Georgia, November, 1987.
11. McCabe, G.J., **Water Budget Analysis of the Nonconnah Drainage Basin in Memphis, Tennessee**, Annual Meeting of the Association of American Geographers, Phoenix, Arizona, April, 1988. (PRESENTED)
12. McCabe, G.J., **General Circulation Model Predictions and Water Balance Analysis for the Delaware River Basin**, report to the Advisory Committee of the Delaware River Basin Climate Change Project, U.S. Geological Survey, Water Resources Division, West Trenton, New Jersey, December, 1988. (PRESENTED)
13. McCabe, G.J., **A Synoptic Climatological Approach to Simulate Climate Change**, report to the Advisory Committee of the Delaware River Basin Climate Change Project, U.S. Geological Survey, Water Resources Division, West Trenton, New Jersey, December, 1988. (PRESENTED)
14. McCabe, G.J. and L.E. Hay, **Precipitation Modeling Using a Synoptic Weather Type Approach**, report to the Advisory Committee of the Delaware River Basin Climate Change Project, U.S. Geological Survey, Water Resources Division, West Trenton, New Jersey, March 1989. (PRESENTED)
15. McCabe, G.J. and L.E. Hay, **Use of Synoptic Weather Types to Develop a Regional Climate Model**, meeting with the Department of Meteorology and Physical Oceanography, Rutgers University, New Brunswick, New Jersey, March 1989. (PRESENTED, INVITED)
16. McCabe, G.J., **A Parabolic Function to Modify Thornthwaite Estimates of Potential Evapotranspiration**, Water Science Center Seminar, U.S. Geological Survey, Water Resources Division, West Trenton, New Jersey, March, 1989. (PRESENTED)
17. McCabe, G.J., **A Parabolic Function to Modify Thornthwaite Estimates of Potential Evapotranspiration**, Annual Meeting of the Association of American Geographers, Baltimore, Maryland, March, 1989. (PRESENTED)
18. McCabe, G.J., L.E. Hay, L.S. Kalkstein, D.M. Wolock, and M.A. Ayers, **Use of Synoptic Weather-Type Classification in a Delaware River Basin Climate Model**, Semi-Annual meeting of the American Geophysical Union, May, 1989. (PRESENTED)

19. Hay, L.E., G.J. McCabe, D.M. Wolock, and M.A. Ayers, **Estimation of Precipitation in the Delaware River Basin Using Synoptic Weather-Type Classification**, Semi-Annual Meeting of the American Geophysical Union, May, 1989.
20. McCabe, G.J., L.E. Hay, L.S. Kalkstein, D.M. Wolock and M.A. Ayers, **Simulation of Precipitation by Weather-Type Analysis**, American Society of Civil Engineers, New Orleans, Louisiana, August, 1989. (PRESENTED, INVITED)
21. McCabe, G.J. and D.M. Wolock, **Effects of Climatic Change in the Delaware River Basin on the Thornthwaite Moisture Index**, American Society of Civil Engineers, New Orleans, Louisiana, August, 1989. (PRESENTED, INVITED)
22. McCabe, G.J., **Choosing and Applying Scenarios of Climatic Change**, NOAA/USGS Hydrologic Research Meeting, Reston, Virginia, November, 1989. (PRESENTED, INVITED)
23. Ayers, M.A., D.M. Wolock, G.J. McCabe, and L.E. Hay, **Simulated Hydrologic Effects of Climate Change in the Delaware River Basin**, Symposium on International and Transboundary Water Resources Issues, American Water Resources Association, Toronto, Canada, April, 1990. (INVITED)
24. McCabe, G.J., L.E. Hay, D. M. Wolock, and M.A. Ayers, **A Weather-Type Model of Temperature and Precipitation under Doubled-CO<sub>2</sub> Conditions**, Annual Meeting of the Association of American Geographers, Toronto, Canada, April, 1990. (PRESENTED)
25. Hay, L.E., G.J. McCabe, D.M. Wolock, and M.A. Ayers, **Use of Weather-Type Analysis to Disaggregate General Circulation Model Predictions**, American Geophysical Union Chapman Conference on Hydrologic Aspects of Global Climate Change, Lake Chelan, Washington, June, 1990.
26. Ayers, M.A., D.M. Wolock, G.J. McCabe, and G.D. Tasker, **Climate Change and Water Resources in the Delaware River Basin**, Chief Hydrologist's Research Seminar, U.S. Geological Survey, Reston, Virginia, October, 1990. (INVITED)
27. Ayers, M.A., G.D. Tasker, D.M. Wolock, G.J. McCabe, and L.E. Hay, **Simulated Effects of Climatic Change on Runoff and Drought in the Delaware River Basin**, American Society of Civil Engineers, San Francisco, California, November, 1990.
28. Ayers, M.A., D.M. Wolock, G.J. McCabe, and L.E. Hay, **Simulated Hydrologic Effects of Climatic Change in the Delaware River Basin**, Geological Association of New Jersey, Keynote Address, November, 1990. (INVITED)
29. McCabe, G.J., **Uncertainty in Predicting the Hydrologic Effects of Climatic Change**, U.S. Geological Survey seminar, Denver Federal Center, Denver, Colorado, January, 1991. (PRESENTED, INVITED)
30. McCabe, G.J., D.M. Wolock, M.A. Ayers, G.D. Tasker, and L.E. Hay, **Sensitivity of Water resources in the Delaware River Basin to Climate Change**, USGS Global Change Forum, Reston, Virginia, March, 1991. (PRESENTED, INVITED)
31. Tasker, G.D., D.M. Wolock, and G.J. McCabe, **A Monthly Water Balance to Study Possible Impacts of Climate Change in the Delaware River Basin**, USGS Global Change Forum, Reston, Virginia, March, 1991.

32. McCabe, G.J., D.M. Wolock, M.A. Ayers, G.D. Tasker, and L.E. Hay, **The Delaware River Basin Climate Change Project**, Delaware River Basin Commission Technical Meeting, Trenton, New Jersey, April, 1991. (PRESENTED)
33. McCabe, G.J., L.E. Hay, D.M. Wolock, and M.A. Ayers, **Use of Weather-Type Analysis to Disaggregate General Circulation Model Predictions**, Annual Meeting of the Association of American Geographers, Miami, Florida, April, 1991. (PRESENTED, INVITED)
34. Tasker, G.D., M.A. Ayers, D.M. Wolock, and G.J. McCabe, **Sensitivity of Drought Risks in the Delaware River Basin to Climate Change**, Technology and Business Exposition and Symposium, Huntsville, Alabama, May, 1991. (INVITED)
35. Wolock, D.M., G.J. McCabe, and G.D. Tasker, **Sources of Uncertainty in Predicting the Effects of Climatic Change on Drought in the Delaware River Basin**, Semi-Annual Meeting of the American Geophysical Union, May, 1991.
36. Wolock, D.M., G.J. McCabe, and G.D. Tasker, **Sources of Uncertainty in Predicting the Effects of Climatic Change on Drought Frequency in the Delaware River Basin**, American Society of Civil Engineers, Nashville, Tennessee, July, 1991. (INVITED)
37. McCabe, G.J., **Applications of Synoptic Climatology in Water Resources Research**, U.S. Geological Survey Conference on Global Change and Sedimentation, Hood, Oregon, September, 1991. (PRESENTED)
38. Tasker, G.D., G.J. McCabe, and D.M. Wolock, **Hydrological Impacts of Climate Change for the Delaware River Basin**, American Water Resources Association, 27th Conference on Water Management of River Systems, New Orleans, September, 1991. (INVITED)
39. Wolock, D.M., G.J. McCabe, G.D. Tasker, and M.E. Moss, **Sensitivity of Water Resources in the Delaware River basin to Climate Change**, International Institute for Applied Systems Analysis, Laxenburg, Austria, October, 1991. (INVITED)
40. Wolock, D.M., G.J. McCabe, and G.D. Tasker, **Sensitivity of a Hydrologic Model of the Delaware River Basin to Climate Change**, The 1st National Conference on Climate Change and Water Resources Management, Albuquerque, New Mexico, November, 1991. (INVITED)
41. McCabe, G.J., and D.M. Wolock, **Development of Scenarios for the Simulation of the Effects of Climate Change on Water Resources**, USGS/Japan Workshop on the Effects of Global Climate Change on Hydrology and Water Resources at a Catchment Scale, Tsukuba, Japan, February, 1992. (PRESENTED, INVITED)
42. McCabe, G.J., D.M. Wolock, and G.D. Tasker, **Sensitivity of a Watershed Model of the Delaware River Basin to Projected Climatic Change**, USGS/Japan Workshop on the Effects of Global Climate Change on Hydrology and Water Resources at a Catchment Scale, Tsukuba, Japan, February, 1992. (PRESENTED, INVITED)
43. McCabe, G.J., D.M. Wolock, and G.D. Tasker, **A Monthly Water Balance Model of the Delaware River Basin**, Annual Meeting of the Association of American Geographers, San Diego, California, April, 1992. (PRESENTED)

44. McCabe, G.J., D.M. Wolock, and G.D. Tasker, **Effects of Reservoir Management and Climatic Change on Water Resources of the Delaware River Basin**, American Water Resources Association, Reno, Nevada, November, 1992. (PRESENTED)
45. McCabe, G.J., **Relations Between Atmospheric Circulation and Snowpack in the Gunnison River Basin, Colorado**, Second USGS/Japan Workshop on the Effects of Global Climate Change on Hydrology and Water Resources at the Catchment Scale, Boulder, Colorado, February, 1993. (PRESENTED, INVITED)
46. McCabe, G.J., **A High Resolution Drought Index for the Gunnison River Basin, Colorado**, seminar at IBM for the Second USGS/Japan Workshop on the Effects of Global Climate Change on Hydrology and Water Resources at the Catchment Scale, Boulder, Colorado, February, 1993. (PRESENTED)
47. McCabe, G.J., **Applications of Synoptic Climatology in Hydrologic Research**, seminar, Public Works Research Institute, Ministry of Construction, Government of Japan, Tsukuba, Japan, March, 1993. (PRESENTED, INVITED)
48. McCabe, G.J., **Relations Between Atmospheric Circulation and Snowpack in the Gunnison River Basin, Colorado**, Annual Meeting of the Association of American Geographers, Atlanta, Georgia, March, 1993. (PRESENTED)
49. Knapp, L., G.J. McCabe, L.E. Hay, and R.S. Parker, **A High Resolution Moisture Index for the Gunnison River Basin, Colorado**, Second International Conference/Workshop on Integrating Geographic Information Systems and Environmental Modeling, NCGIA, Breckenridge, Colorado, September, 1993.
50. McCabe, G.J., **Hydrologic Studies in the Gunnison River Basin, Colorado**, USGS/Japan Colorado River Workshop Tour, October, 1993. (PRESENTED, INVITED)
51. McCabe, G.J., D.R. Legates, and M.D. Dettinger, **Relations Between 700-millibar Height Anomalies April 1 Snowpack Accumulations in the Western United States**, Eighteenth Climate Diagnostics Workshop, Boulder, Colorado, November, 1993. (PRESENTED)
52. Dettinger, M.D., D.R. Cayan, and G.J. McCabe, **Decadal Trends in Runoff Over the Western United States and Links to Persistent North Pacific Sea-Surface Temperature and Atmospheric- Circulation Patterns**, Eighteenth Climate Diagnostics Workshop, Boulder, Colorado, November, 1993.
53. Hay, L.E., G.J. McCabe, and L. Knapp, **Evaluation of an Orographic Precipitation Model Using Scientific Visualization**, Annual Meeting of the Association of American Geographers, San Francisco, California, March, 1994.
54. McCabe, G.J., **Atmospheric Circulation and Snowpack in the Gunnison River Basin**, American Society of Civil Engineers, Denver, Colorado, May, 1994. (PRESENTED)
55. McCabe, G.J., and L.E. Hay, **Hydrologic Effects of Hypothetical Climate Change in the East River Basin, Colorado**, Annual Summer Symposium, American Water Resources Association, Jackson Hole, Wyoming, June, 1994. (PRESENTED)

56. McCabe, G.J., and T. Yonetani, **Abrupt Changes in Regional Temperature in the Conterminous United States**, Third Japan/USGS Workshop on Hydrology, Water Resources, and Global Climate Change, Tsukuba, Japan, February, 1995. (PRESENTED, INVITED)
57. McCabe, G.J., and D. Wolock, **Effects of Climate, Topography, and Soils on Streamflow Generation**, USGS Surface Water Discipline Seminar, U.S. Geological Survey National Training Center, Denver Colorado, March, 1995. (PRESENTED)
58. McCabe, G.J., **Atmospheric Circulation, Sea-Surface Temperatures, and Mass Balance of South Cascade Glacier**, Seminar, Center for Climatic Research, Department of Geography, University of Delaware, Newark, Delaware, April, 1995. (PRESENTED, INVITED)
59. McCabe, G.J., and A.G. Fountain, **Relations Between Atmospheric Circulation and the Mass Balance of South Cascade Glacier, Washington**, Annual Summer Symposium, American Water Resources Association, Honolulu, Hawaii, June, 1995. (PRESENTED)
60. McCabe, G.J., **Winter Atmospheric Circulation and Temporal and Spatial Distributions of Annual Streamflow in the Western United States**, 16th Annual AGU Hydrology Days, Fort Collins, Colorado, April, 1996. (PRESENTED)
61. Hay, L.E., R. Viger, and G.J. McCabe, **Precipitation and Temperature Interpolation in Mountainous Regions on a Daily Time Step**, Annual Conference on Water Resources, American Water Resources Association, Long Beach, California, October, 1997.
62. McCabe, G.J., **Relations Between Pacific Ocean Climate and Hydrology of the Western United States**, Symposium on Climate Variability, Climate Change, and Water Resource Management, Colorado Springs, October, 1997. (PRESENTED, INVITED)
63. McCabe, G.J., **Relations Between Pacific Ocean Climate and the Hydroclimate of the United States**, Region 6 Climate Change Workshop, Dallas, Texas, October, 1997. (PRESENTED, INVITED)
64. McCabe, G.J., and D.M. Wolock, **Climate Change and the Detection of Trends in Annual Runoff**, Annual Meeting of the Association of American Geographers, Boston, Massachusetts, March, 1998. (PRESENTED)
65. Hay, L.E., R. Viger, G. McCabe, **Precipitation Interpolation in Mountainous Regions Using Multiple Linear Regression**. HeadWater'98 Conference, Meran/Merano, Italy, April, 1998.
66. McCabe, G.J., and M.D. Dettinger, **Decadal Variability in the Strength of ENSO Teleconnections with Precipitation in the Western United States**, PACLIM, Two Harbors, Santa Catalina Island, April, 1998. (PRESENTED)
67. Hay, L.E., and McCabe, G.J., **Weather-type Based Precipitation Interpolation for Rainfall-Runoff Modeling**. Spring Meeting of the American Geophysical Union, Boston, Massachusetts, May, 1998.
68. McCabe, G.J., and M.D. Dettinger, **Decadal Variability in the Strength of ENSO Teleconnections with Precipitation in the Western United States**, Annual Meeting of the Association of American Geographers, Honolulu, Hawaii, March, 1999. (PRESENTED)

69. Clark, M.P., M. Serreze, and G.J. McCabe, **The Influence of ENSO on Water Resources in the Western United States**, Annual Meeting of the Association of American Geographers, Honolulu, Hawaii, March, 1999.
70. McCabe, G.J., and D.M. Wolock, **General-Circulation-Model Simulations of Future Snowpack in the Western United States**, Specialty Conference on Potential Consequences of Climate Variability and Change to Water Resources of the United States, American Water Resources Association, American Water Resources Association, Atlanta, Georgia, May, 1999. (PRESENTED, INVITED)
71. Wolock, D.M., and G.J. McCabe, **Simulated Effects of Climate Change on Mean Annual Runoff in the Conterminous United States**, Specialty Conference on Potential Consequences of Climate Variability and Change to Water Resources of the United States, American Water Resources Association, Atlanta, Georgia, May, 1999. (INVITED)
72. Diaz, H.F., and G.J. McCabe, **A Possible Connection Between the 1878 Yellow Fever Epidemic in the Southern United States and the 1877-78 El Nino Episode**, 16th Annual Pacific Climate (PACCLIM) Workshop, Two Harbors, Santa Catalina Island, May 1999. (PRESENTED, INVITED)
73. Clark, M.P., M. Serreze, and G.J. McCabe, **The Influence of ENSO on Water Resources in the Western United States**, 16th Annual Pacific Climate (PACCLIM) Workshop, Two Harbors, Santa Catalina Island, May 1999. (INVITED)
74. Clark, M.P., Hay, L.E., McCabe, G.J., Leavesley, G.H., Serreze, M.C., and Wilby, R.L., **The Use of Weather and Climate Information in Management of Water Resources in the Western United States**, Plenary Paper for the Special Conference on Climate Variability and Water Resources, Boulder, Colorado, June 1999. (INVITED)
75. Clark, M.P., Hoerling, M.P., Wolter, K., Ray, A.J., Serreze, M.C., and McCabe, G.J., **Use of ENSO Information in Improving Seasonal Water Supply Outlooks**, American Meteorological Society, January, 2000.
76. McCabe, G.J., **Water Resources Impacts of Climate Variability and Change**, USGS Western Region Climate Workshop, La Jolla, California, February 9-10, 2000. (PRESENTED, INVITED)
77. McCabe, G.J., and M.D. Dettinger, **North Pacific Modulation of ENSO Teleconnections with Winter Precipitation in the Western United States**, International Workshop on River Environments Considering Hydraulic and Hydrologic Phenomena in Snowy and Cold Regions, Quebec, Canada, March 20-23, 2000. (PRESENTED, INVITED)
78. McCabe, G.J., and D.M. Wolock, **Estimates of Runoff Using Water-Balance and Atmospheric General Circulation Models**, Annual Meeting of the Association of American Geographers, Pittsburgh, Pennsylvania, April 4-7, 2000. (PRESENTED)
79. Muller, R.A., and G.J. McCabe, **A Climatic Water-Budget Interpretation of the 1999 Northeastern Drought**, Annual Meeting of the Association of American Geographers, Pittsburgh, Pennsylvania, April 4-7, 2000.

80. Dettinger, M.D., and G.J. McCabe, **El Nino, Pacific Decadal Oscillation, and Historical Drought/ Flood Episodes in Western North America and Eastern Siberia**, Paleoclimate and People Workshop, Fort Burgwin, New Mexico, June 8-9, 2000. (INVITED)
81. McCabe, G.J., **U.S. Geological Survey Hydrologic Programs and Future Needs**, National Research Council Workshop on Predictability and Limits-of-Prediction for Hydrologic Sciences, Boulder, Colorado, September 21-22, 2000. (PRESENTED, INVITED)
82. Clark, M.P., R.L. Wilby, L.E. Hay, G.J. McCabe, and G.H. Leavesley, **Towards the Use of Atmospheric Forecasts in Hydrologic Models. Part 1. Forecast Drift and Scale Dependencies**, American Geophysical Union, San Francisco, California, December, 2000.
83. McCabe, G.J. and R.A. Muller, **Effects of Tropical Pacific Sea-Surface Temperatures on New Orleans Weather Type Frequencies and Characteristics**. Annual Meeting of the Association of American Geographers, New York, New York, February 28, 2001. (PRESENTED, INVITED)
84. McCabe, G.J., **Pacific Ocean Teleconnections with Western U.S. Hydroclimate**. Seminar, Denver Chapter of the American Meteorological Society, Metropolitan State College of Denver, Denver, Colorado, March 14, 2001. (PRESENTED, INVITED)
85. McCabe, G.J., **Primary Modes and Predictability of Year-to-Year Snowpack Variations in the Western United States From Teleconnections with Pacific Ocean Climate**. 18th Annual Pacific Climate (PACCLIM) Workshop, Pacific Grove, California, March 18-24, 2001. (PRESENTED)
86. Clark, M.P., M.P. Hoerling, A.J. Ray, K. Wolter, M.C. Serreze, and G.J. McCabe. **Use of ENSO Information in Improving Seasonal Water Supply Outlooks**. 18th Annual Pacific Climate (PACCLIM) Workshop, Pacific Grove, California, March 18-24, 2001. (PRESENTED)
87. Meier, M., M. Dyurgerov, and G.J. McCabe. **The Health of Glaciers: Recent Changes in Glacier Regime**. Davos, Switzerland, June, 2001. (INVITED)
88. McCabe, G.J., and D.M. Wolock, **Is Streamflow Increasing in the Conterminous United States?**, 19th Annual Pacific Climate (PACCLIM) Workshop, Pacific Grove, California, March, 2002. (PRESENTED)
89. McCabe, G.J., S. Markstrom, and O. David, **Web-Based Distribution of Hydrologic Models**. Annual Meeting of the Association of American Geographers, Los Angeles, California, March, 2002. (PRESENTED)
90. McCabe, G.J. **Hydroclimatology of the 2002 Drought**. Central Region Executive Leadership Seminar, U.S. Geological Survey, Denver, Colorado, June, 2002. (PRESENTED, INVITED)
91. Wolock, D.M. and G.J. McCabe, **Trends in the 20th Century**. U.S. Geological Survey Water Science Center Seminar, Kansas Water Science Center, Lawrence, Kansas, October, 2002. (INVITED)
92. McCabe, G.J. and D.M. Wolock, **Streamflow Trends in the Conterminous United States**. U.S. Geological Survey Central Region Colloquium, Denver, Colorado, January, 2003. (INVITED, PRESENTED)

93. Palecki, M.A., and G.J. McCabe. **Midwestern Drought**. 83rd Annual Meeting of the American Meteorological Society, Long Beach, California, February, 2003.
94. Anderson, D., and G.J. McCabe, **Can Global Surface Pressure be Used as an Indicator of Surface Temperature?** Annual Meeting of the American Association for the Advancement of Science, Denver, February, 2003.
95. McCabe, G.J. and D.M. Wolock, **A Step Increase in Streamflow in the Conterminous United States**. Annual Meeting of the Association of American Geographers, New Orleans, Louisiana, March, 2003. (PRESENTED)
96. Bunnell, J.E., S.D. Price, and G.J. McCabe. **Environmental Predictors for Tick Borne Disease Risk in the Middle Atlantic Region**, USA. U.S. Geological Survey Health Conference, April, 2003.
97. McGinnis, D., and G.J. McCabe. **700-HectoPascal Atmospheric Circulation Patterns Associated with Winter Precipitation in the Yellowstone Region**. 19th Annual Pacific Climate (PACCLIM) Workshop, Pacific Grove, California, March, 2003.
98. Dettinger, M.D., and G.J. McCabe. **Hydroclimatology of Southwestern Drought**. Southwest Drought Summit, Flagstaff, Arizona, May, 2003. (INVITED)
99. Betancourt, J.L., S. Gray, G.J. McCabe, L. Gramlich, M. Palecki, and G. Pederson, **The current drought in historical context**, Workshop on Land Management in a Changing Climate, Sustainable Technologies, Agribusiness and Resources (STAR) Research Center and Department of Applied Biological Sciences, Arizona State University East Campus, Mesa, Arizona, May, 2003. (INVITED)
100. Palecki, M.A., and G.J. McCabe, **The Role of Multi-Decadal Modes in Drought Frequency**. North American Drought Monitor Workshop, National Climatic Data Center, Asheville, North Carolina, June 25-27, 2003.
101. Betancourt, J.L., S. Gray, G.J. McCabe, L. Gramlich, M. Palecki, and G. Pederson, **The current drought in historical perspective**, Citizen's Water Advisory Council, Tucson Water, Sept. 9, 2003. (INVITED)
102. Betancourt, J.L., S. Gray, G.J. McCabe, L. Gramlich, M. Palecki, and G. Pederson, **PDO, AMO, and megadrought in the Western U.S.**, Annual Symposium of the Arizona Hydrological Society, Mesa, Arizona, Sept. 19, 2003.
103. Betancourt, J.L., S. Gray, G.J. McCabe, L. Gramlich, M. Palecki, and G. Pederson, **PDO, AMO, and megadrought in the Western U.S.**, departmental seminar, Laboratory of Tree-Ring Research, University of Arizona, Sept. 24, 2003. (INVITED)
104. Betancourt, J.L., S. Gray, G.J. McCabe, L. Gramlich, M. Palecki, and G. Pederson, **PDO, AMO, and megadrought in the Western U.S.**, Society for Earth Sciences Students, University of Arizona, Sept. 26, 2003. (INVITED).
105. McCabe, G.J., **Large-Scale Climate Dynamics and Hydro-Climate Variability in the United States**, Center for Science and Technology Policy Research, University of Colorado, September, 2003 (PRESENTED, INVITED).



106. Betancourt, J.L., S. Gray, G.J. McCabe, L. Gramlich, M. Palecki, and G. Pederson, **Historic and modern megadroughts, their causes and impacts**, departmental seminar, University of Nevada, Reno, Ecology Evolution & Conservation Biology Program, October 8, 2003. (INVITED)
107. Betancourt, J.L., S. Gray, G.J. McCabe, L. Gramlich, M. Palecki, and G. Pederson, **Historical and climate context for ongoing drought in the western U.S.**, Meeting of the Western Coalition of Arid States, Tucson, Oct. 30, 2003. (INVITED KEYNOTE TALK)
108. Battaglin, W.A., L.E. Hay, G.J. McCabe, P.K. Nanjappa, and A.L. Gallant, **Associations Between Amphibian diversity and climate in the continental United States**, abstract 100, abstract book, SETAC 24th Annual Meeting in North America, Society of Environmental Toxicology and Chemistry, Pensacola, Florida, November, 2003.
109. Betancourt, J.L., S. Gray, G.J. McCabe, L. Gramlich, M. Palecki, and G. Pederson, **PDO, AMO, and megadrought in the Western U.S.**, PAGES/CLIVAR/IPCC Workshop, A multi-millennia perspective on drought and implications for the future, Tucson, Nov. 18-21, 2003.
110. McCabe, G.J., Palecki, M.A., J.L. Betancourt, and M.D. Dettinger, **Ghosts of Drought: Past, Present and Future**, U.S. Geological Survey National Surface Water Conference, San Antonio, Texas, November, 2003. (PRESENTED, INVITED)
111. Betancourt, J.L., G.J. McCabe, M.A. Palecki, S.T. Gray, and L. Gramlich, **AMO, PDO, and Severe Droughts in the Conterminous US: A Southwestern Perspective**, CLIVAR/PAGES/IPCC Workshop, Tucson, Arizona, November 2003. (INVITED)
112. Betancourt, J.L., S. Gray, G.J. McCabe, L. Gramlich, M. Palecki, and G. Pederson, **Historical and climatic context of severe drought in the western U.S.**, departmental seminar, School of Life Sciences, Arizona State University, Dec. 2, 2003. (INVITED)
113. McCabe, G.J., **USGS Hydroclimatic Research**, seminar for visiting Chinese delegation, Denver Federal Center, Denver, Colorado, December, 2003. (PRESENTED, INVITED)
114. Betancourt, J.L., S. Gray, G.J. McCabe, L. Gramlich, M. Palecki, and G. Pederson, **Historical and climatic context of severe drought in the western U.S.**, Annual Meeting of the Society for Range Management, Salt Lake City, Jan. 29, 2004. (INVITED)
115. McCabe, G.J., **Hydroclimate of the Western United States**, Upper Klamath Basin Science Workshop, Klamath Falls, Oregon, February, 2004. (PRESENTED, INVITED)
116. McCabe, G.J., J.L. Betancourt, M.A. Palecki, and M.D. Dettinger, **Hydroclimatology of Drought and the Future of Water Resources in the Western United States**, Institute for the Study of Planet Earth, University of Arizona, Tucson, Arizona, February, 2004. (PRESENTED, INVITED)
117. Betancourt, J.L., S. Gray, G.J. McCabe, L. Gramlich, M. Palecki, and G. Pederson, **Historical and climatic context of severe drought in the western U.S.**, National Forest Health Monitoring Conference, USDA-Forest Service, Sedona, Arizona February 10, 2004. (INVITED PLENARY TALK)
118. McCabe, G.J., **Hydroclimatology of the Western United States**, CIRES seminar, University of Colorado, Boulder, Colorado, March, 2004. (PRESENTED, INVITED)

119. McCabe, G.J., J.L. Betancourt, M.A. Palecki, and M.D. Dettinger, **Decadal-Scale Variability and the Hydroclimatology of Drought**, Western Governors Association Drought Workshop, Phoenix, Arizona, March, 2004. (PRESENTED, INVITED)
120. McCabe, G.J., M.A. Palecki, and J.L. Betancourt, **Pacific and Atlantic Influences on Multidecadal Drought Frequency in the United States**, Association of American Geographers, Philadelphia, Pennsylvania, March, 2004. (PRESENTED, INVITED)
121. McGinnis, D.L., G.J. McCabe, and H.K. Conely, **Teleconnections and Synoptic Classification using Self-Organizing Maps and Snowfall in the Greater Yellowstone Area**, Association of American Geographers, Philadelphia, Pennsylvania, March, 2004.
122. McCabe, G.J., M.A. Palecki, and J.L. Betancourt, **Pacific and Atlantic Influences on Multidecadal Drought Frequency in the United States**, Pacific Climate (PACCLIM Workshop), Monterey, California, March, 2004. (PRESENTED)
123. Betancourt, J.L., S. Gray, G.J. McCabe, L. Gramlich, M. Palecki, and G. Pederson, **Historical and climatic context of severe drought in the western U.S.**, USGS, WRD, New Mexico Water Science Center, USGS Lecture Series, Albuquerque, March 23, 2004. (INVITED)
124. Betancourt, J.L., S. Gray, G.J. McCabe, L. Gramlich, M. Palecki, and G. Pederson, **Historical and climatic context of severe drought in the western U.S.**, departmental seminar, Dept. of Earth and Planetary Sciences, University of New Mexico, Albuquerque, March 23, 2004. (INVITED)
125. Betancourt, J.L., S. Gray, G.J. McCabe, L. Gramlich, M. Palecki, and G. Pederson, **Historical and climatic context of severe drought in the western U.S.**, Western South Dakota Hydrology Conference, and USGS, WRD Lecture Series, April 6, 2004. (INVITED LUCHEON TALK)
126. Betancourt, J.L., S. Gray, G.J. McCabe, L. Gramlich, M. Palecki, and G. Pederson, **PDO, AMO, and megadrought in the Western U.S.**, USGS lecture, Kansas Water Science Center, Lawrence, Kansas, April 19, 2004. (INVITED)
127. McCabe, G.J., M.A. Palecki, J.L. Betancourt, **Ocean Influences on Multi-Decadal Drought**, National Research Program Seminar, Denver, Colorado, April, 2004. (PRESENTED, INVITED)
128. Palecki, M.A., and G.J. McCabe, **Droughts in the U.S.: Are Conditions Changing**, Central Illinois Chapter of the American Meteorological Society, Clinton, Illinois, May, 2004. (INVITED)
129. Lins, H., G. McCabe, **Highlights of Recent USGS Hydrologic Research**, U.S. Geological Survey Research Committee Meeting, Washington, D.C., May, 2004. (INVITED)
130. McCabe, G.J. radio interview on **Oceans and Drought**, Earth and Sky Radio Series, May, 2004. (PRESENTED, INVITED)
131. Palecki, M.A., and G.J. McCabe, **Droughts in the U.S.: Are Conditions Changing**, Central Illinois Chapter of the American Meteorological Society, Clinton, Illinois, May, 2004. (INVITED)

132. McCabe, G.J., M.A. Palecki, and J.L. Betancourt, **Hydroclimatology of Drought in the Western United States**, Central Region Executive Leadership Team, U.S. Geological Survey, Denver, Colorado, June, 2004. (PRESENTED, INVITED)
133. McCabe, G.J., M.A. Palecki, and J.L. Betancourt, **Historical Context of Drought in the Western United States**, Department of Interior Western Drought Communications Workshop, Denver, Colorado, June, 2004. (PRESENTED, INVITED)
134. Betancourt, J.L., S. Gray, and G.J. McCabe, **Pre-historic Context of Drought**, Department of Interior Western Drought Communications Workshop, Denver, Colorado, June, 2004. (INVITED)
135. Betancourt, J.L., G.J. McCabe, and M.D. Dettinger, **Insights to the Future**, Department of Interior Western Drought Communications Workshop, Denver, Colorado, June, 2004. (INVITED)
136. McCabe, G.J., J.L. Betancourt, and M.A. Palecki, **Drought: Paleoclimatic and Climate Context**, Annual meeting of the Nebraska Water Resources Association and the Nebraska State Irrigation Association, Kearney, Nebraska, November, 2004. (PRESENTED, INVITED KEYNOTE TALK)
137. Palecki, M.A., and G.J. McCabe, **Drought Frequency Variations at Regional, National, and International Scales**, Seminar, Mid-western Regional Climate Center, Illinois State Water Survey, Champaign, Illinois, November, 2004. (INVITED)
138. McCabe, G.J., J.L. Betancourt, and M.A. Palecki, **Drought: Historic Context, Drought, Climate Variability, and Water Supply Workshop**, Colorado Water Science Center, Denver, Colorado, January, 2005. (PRESENTED, INVITED)
139. Betancourt, J.L., S. Gray, G.J. McCabe, and H.G. Hidalgo, **Prehistoric Context for Western Drought, Climate Variability, and Water Supply Workshop**, Colorado Water Science Center, Denver, Colorado, January, 2005. (INVITED)
140. McCabe, G.J., J.L. Betancourt, and M.A. Palecki, **Climate Variability: Paleoclimatic and Historic Contexts**, seminar, Nebraska Water Science Center, Lincoln, Nebraska, February, 2005. (PRESENTED, INVITED)
141. McCabe, G.J., J.L. Betancourt, and M.A. Palecki, **Climate Variability: Prehistoric and Historic Contexts**, seminar, North Dakota State Water Commission, Bismarck, North Dakota, February, 2005. (PRESENTED, INVITED)
142. Webb, R.H., G.J. McCabe, R. Hereford, **Drought, the Colorado River, and Grand Canyon Resources**, Geomorphology Symposium, Flagstaff, Arizona, February, 2005.
143. McCabe, G.J., M.P. Clark, and L.E. Hay, **Temporal and Spatial Variability of Rain-on-Snow Events in the Western United States**, 2005 Mountain Climate Workshop, Pray, Montana, March, 2005. (PRESENTED)
144. McGinnis, D., and G.J. McCabe, **Extending Greater Yellowstone Area Snotel Records Using Synoptic**

**Climatology**, Mountain Climate Workshop, Pray, Montana, March, 2005.

145. McCabe, G.J., J.L. Betancourt, and M.A. Palecki, **Decadal and Multi-decadal Climate Variability: Paleoclimatic and Historic Contexts**, Northern Colorado Water Conservancy Water Science Center, Berthoud, Colorado, March, 2005. (PRESENTED, INVITED)
146. McCabe, G.J., J.L. Betancourt, and M.A. Palecki, **Decadal and Multi-decadal Climate Variability: Paleoclimatic and Historic Contexts**, Colorado Water Availability Task Force, Denver, Colorado, March, 2005. (PRESENTED, INVITED)
147. McCabe, G.J., and M.A. Palecki, **Decadal and Multi-Decadal Variability of Global Palmer Drought Severity Index Values**, Association of American Geographers, Denver, Colorado, April, 2005. (PRESENTED)
148. Palecki, M.A., and G.J. McCabe, **Multi-Decadal Variability of the Level of Great Lakes Michigan and Huron**, Association of American Geographers, Denver, Colorado, April, 2005.
149. McGinnis, D.L., and G.J. McCabe, **Synoptic Climate Sequences and Snowpack Conditions in the Greater Yellowstone Area**, Association of American Geographers, Denver, Colorado, April, 2005.
150. Gray, S.T., J.L. Betancourt, and G.J. McCabe, **The Relationship Between Reconstructed PDO, AMO, and North American Drought Patterns: Implications for Proxy Development**, Association of American Geographers, Denver, Colorado, April, 2005.
151. McCabe, G.J., J.L. Betancourt, and H.G. Hidalgo, **Association of Decadal to Multi-Decadal Sea- Surface Temperature Variability with Flow of the Upper Colorado River Basin**, Planning Workshop to Develop Hydroclimatic Reconstructions for Decision Support in the Colorado River Basin, Tucson, Arizona, May, 2005. (INVITED)
152. McCabe, G.J., and J.L. Betancourt, **Climate Variability: Paleoclimatic and Historic Contexts**, Boulder Creek Watershed Forum, Boulder, Colorado, May, 2005. (PRESENTED, INVITED)
153. McCabe, G.J., J.L. Betancourt, S.T. Gray, M.A. Palecki, and H.G. Hidalgo, **Associations of Multi-Decadal Sea-Surface Temperature Variability with U.S. Drought**, 2006 Pacific Climate (PACCLIM) Workshop, Monterey, California, March, 2006. (PRESENTED, INVITED)
154. McCabe, G.J., J.L. Betancourt, S.T. Gray, M.A. Palecki, and H.G. Hidalgo, **Associations of Multi-Decadal Sea-Surface Temperature Variability with U.S. Hydroclimate**, Hydrologic Sciences and Water Resources Engineering seminar, University of Colorado, Boulder, Colorado, April, 2006. (PRESENTED, INVITED)
155. McCabe, G.J., **Use of Paleoclimate Reconstructions as Climate Scenarios**, Joint Bureau of Reclamation and U.S. Geological Survey Briefing/Workshop, Denver, Colorado, April, 2006. (PRESENTED, INVITED)
156. McCabe, G.J., and D.M. Wolock, **Regime Shifts: An Issue for Water Resource Management**, American Water Resources Association 2006 Annual Symposium, Colorado Section, Denver, Colorado, April, 2006. (PRESENTED, INVITED)

157. McCabe, G.J., and D.M. Wolock, **Hydrologic Effects of Climate Variability and Change: Issues and Research Approaches**, USGS Central Region Science Workshop, Denver, Colorado, June, 2006. (PRESENTED, INVITED)
158. McCabe, G.J., J.L. Betancourt, S.T. Gray, M.A. Palecki, and H.H. Hidalgo, **Decadal-to-Multidecadal (D2M) Variability in Global SSTs and North American Hydroclimate: An Update and Prospectus for Paleoscience**. 18<sup>th</sup> Biennial conference of the American Quaternary Association (AMQUA), Bozeman, Montana, August, 2006. (PRESENTED, INVITED)
159. McCabe, G.J., J.L. Betancourt, S.T. Gray, M.A. Palecki, and H.G. Hidalgo, **Patterns, Sources, and Impacts of Decadal-to-Multidecadal Climate Variability**, seminar, Department of Earth and Environmental Sciences, Lehigh University, Bethlehem, Pennsylvania, October, 2006. (PRESENTED, INVITED)
160. McCabe, G.J., and D.M. Wolock, **Variability and Trends in Mississippi River Basin Streamflow: Implications for the Gulf Hypoxic Zone**, Science Symposium: Sources, Transport, and Fate of Nutrients in the Mississippi and Atchafalaya River Basins, Minneapolis, Minnesota, November, 2006. (PRESENTED, INVITED)
161. McCabe, G.J., J.L. Betancourt, S.T. Gray, M.A. Palecki, and H.H. Hidalgo, **Decadal-to-Multidecadal (D2M) Variability in Global SSTs and North American Hydroclimate**. Joint USGS/Public Works Research Institute of Japan meeting, January, 2007. (PRESENTED, INVITED)
162. McCabe, G.J., and D.M. Wolock, **Climate Change and Global runoff**, Director's briefing, U.S. Geological Survey, Denver, Colorado, March, 2007. (PRESENTED, INVITED)
163. McCabe, G.J., J.L. Betancourt, S.T. Gray, M.A. Palecki, and H.G. Hidalgo, **Patterns, Sources, and Impacts of Decadal-to-Multidecadal Climate Variability**, U.S. Geological Survey National Surface water Conference, St. Louis, Missouri, April, 2007. (PRESENTED, INVITED)
164. McCabe, G.J., J.L. Betancourt, S.T. Gray, M.A. Palecki, and H.G. Hidalgo, **Global Sea-Surface Temperatures and North American Droughts and Pluvials**, seminar, National Research Program, U.S. Geological Survey, Denver, Colorado, April, 2007. (PRESENTED, INVITED)
165. McCabe, G.J., **North American Drought: Paleoclimatic and Historic Context**, Joint USGS/USACE/USBOR/NOAA workshop, Washington, D.C., May, 2007. (PRESENTED, INVITED)
166. McCabe, G.J., and D.M. Wolock, **Water in the West: Squeezing Water from a Stone**, Annual South Platte River Forum, Longmont, Colorado, October, 2007. (PRESENTED, INVITED)
167. McCabe, G.J., and D.M. Wolock, **Water Use and Warming: Implications for Water Supply in the Colorado River Basin**, 2007 Nevada Water Resources Association Climate Change Symposium, Las Vegas, Nevada, November, 2007. (PRESENTED)
168. Hay, L.E., and G.J. McCabe, **Hydrologic Effects of Climate Change in the Yukon River Basin**, seminar, Colorado Water Science Center, Denver, Colorado, January, 2008. (INVITED)

169. Betancourt, J.L., and G.J. McCabe, **Drought: the Long, Slow Natural Hazard (Part 1)**, U.S. Geological Survey Podcast. (host: David Hebert), [www.usgs.gov/corecast](http://www.usgs.gov/corecast), episode 33, March, 2008. (PRESENTED, INVITED)
170. McCabe, G.J., appearance in a National Geographic documentary, April, 2008. (INVITED)
171. McCabe, G.J., and D.M. Wolock, **Effects of Warming on Water Supply in the Colorado River Basin**, Association of American Geographers, Boston, Massachusetts, April, 2008. (PRESENTED, INVITED)
172. McCabe, G.J. and D.M. Wolock, **Streamflow trends in the Conterminous United States**, Joint Services Environmental Management Conference, Denver, Colorado, May, 2008. (PRESENTED, INVITED)
173. McCabe, G.J., and D.M. Wolock, **Warming and implications for water supply in the Colorado River Basin**, Proceedings of the 2008 World Environmental and Water Congress, American Society of Civil Engineers, Honolulu, Hawaii, May, 2008. (PRESENTED, INVITED)
174. Hay, L.E., and G.J. McCabe, **Hydrologic effects of climate change in the Yukon River Basin**, Proceedings of the 2008 World Environmental and Water Congress, American Society of Civil Engineers, Honolulu, Hawaii, May, 2008. (INVITED)
175. McCabe, G.J., and D.M. Wolock, **Sensitivity of water supply in the Colorado River Basin to warming**, USGS seminar, Branch of Regional Research, Eastern Region, Reston, Virginia, June, 2008. (PRESENTED, INVITED)
176. McCabe, G.J., and D.M. Wolock, **Sensitivity of water supply in the Colorado River Basin to warming**, Congressional Briefing on Climate Change Impacts on the Colorado River, Washington, D.C., June, 2008. (PRESENTED, INVITED)
177. McCabe, G.J., and D.M. Wolock, **Warming and potential water supply shortages**, Glen Canyon Institute conference on adjusting to less water: climate change and the Colorado River, University of Utah, Salt Lake City, Utah, December, 2008. (PRESENTED, INVITED)
178. McCabe, G.J., and D.M. Wolock, **Sustainability of water supply in the Colorado River basin**, seminar, Department of Geography, University of Colorado, Boulder, Colorado, February, 2009. (PRESENTED, INVITED)
179. McCabe, G.J., and D.M. Wolock, **Sensitivity of water supply in the Colorado River Basin to warming**, Rocky Mountain Land Use Conference, University of Denver, Denver, Colorado, March, 2009. (PRESENTED, INVITED)
180. McCabe, G.J., and D.M. Wolock, **Recent declines in western US snowpack in the context of 20<sup>th</sup> century climate variability**, Annual Meeting of the Association of American Geographers, Las Vegas, Nevada, March 2009. (PRESENTED)
181. Brekke, L., L. Hay, E. Clark, N. Parker, T. Pruitt, and G. McCabe, **Preferences among hydrologic models for studies involving climate change?** American Water Resources Association, Seattle, Washington,

November, 2009.

182. McCabe, G.J., and D.M. Wolock, **Warming may create substantial water supply shortages in the Colorado River Basin**, seminar, Engineering Center, University of Colorado, Boulder, Colorado, November, 2009. (PRESENTED, INVITED).
183. McCabe, G.J. **The Atlantic Multidecadal Oscillation**, Eastern Seasonal Assessment Workshop, January 2010. (PRESENTED, INVITED)
184. McCabe, G.J. and D.M. Wolock, **Recent declines in western US snowpack in the context of 20<sup>th</sup> century climate variability**, U.S. Geological Survey Climate Change Science Conference, Denver, Colorado, March 2010.
185. McCabe, G.J., and D.M. Wolock, **Century-scale variability in global annual runoff examined using a water balance model**, Annual Meeting, Association of American Geographers, Washington, D.C., April 2010. (PRESENTED)
186. Gray, S., S. Jackson, G. McCabe, J. Lukas, B. Shuman, G. Pederson, and C. Woodhouse, **Applying the paleoenvironmental record to critical problems in water resource management**, Annual Meeting, Association of American Geographers, Washington, D.C., April, 2010.
187. Walker, J.F., L.E. Hay, N. Booth, G. McCabe, S. Markstrom, and J. LaFontaine, **Towards a national hydrologic model: overview**, 3<sup>rd</sup> U.S. Geological Survey Modeling Conference, June, 2010.
188. McCabe, G.J. and D.M. Wolock, **A national water balance model**, 3<sup>rd</sup> U.S. Geological Survey Modeling Conference, Denver, Colorado, June, 2010. (PRESENTED, INVITED)
189. Gray, S.T., G.J. McCabe, and G.T. Pederson, **Vulnerability of high elevation watersheds under climate change: case studies from the northern Rocky Mountains**, Annual Meeting, American Water Resources Association, Philadelphia, Pennsylvania, November, 2010.
190. Hay, L.E., S. Markstrom, G.J. McCabe, R. Viger, J. Walker, and N. Booth, **Towards a National Hydrologic Model**, Annual Meeting, Geological Society of America, Denver, Colorado, November, 2010. (INVITED)
191. McCabe, G.J., and D.M. Wolock, **Effects of temperature and precipitation on modeled runoff in the conterminous U.S. during the 20<sup>th</sup> Century**, USGS National Surface Water Conference and Hydroacoustics Workshop, Tampa, Florida, March, 2011. (PRESENTED)
192. Wolock, D.M. and G.J. McCabe, **Effects of spatial patterns in climate on losing and gaining streams**, USGS National Surface Water Conference and Hydroacoustics Workshop, Tampa, Florida, March, 2011.
193. Poole, S., L. Hay, G. McCabe, S. Markstrom, D. Wolock, N. Booth, and D. Atkinson, **National water balance model**. USGS National Surface Water Conference and Hydroacoustics Workshop, Tampa, Florida, March, 2011.
194. McCabe, G.J., and D.M. Wolock, **A national water balance model**. Annual Meeting, Association of

American Geographers, Seattle, Washington, April, 2011. (PRESENTED)

195. Hay, L.E., G. McCabe, S. Poole, S. Markstrom, D. Wolock, N. Booth, and D. Atkinson, **National Water Balance Model for Current and Future Conditions**, American Water Resources Association, Baltimore, Maryland, April, 2011.
196. McCabe, G.J., and D.M. Wolock, Recent Declines in Western U.S. **Snowpack in the Context of 20<sup>th</sup> Century Climate Variability**. World Climate Research Program, Denver, Colorado, October, 2011. (PRESENTED)
197. McCabe, G.J., and D.M. Wolock, **Variability of annual minimum flows in the conterminous U.S.**, NOAA U.S. National Assessment workshop, Trends and causes of observed changes in heat waves, cold waves, floods and drought, Climate Science Working Group of the National Climate Assessment, National Climatic Data Center, Asheville, North Carolina, November, 2011. (PRESENTED, INVITED)
198. Betancourt, J.L., Schwartz, M.D., T.R. Ault, I. Park, G.J. McCabe, A. Macalady, G.T. Pederson, B.I. Cook, G.M. Henebry, D.J.P. Moore, and C. Enquist, **The Spring Index (SI): A National (and Global) Indicator of Climate Impacts on Ecosystems and Society**. American Geophysical Union, San Francisco, California, December, 2011.
199. Dudley, R.W., M.R. McHale, G.A. Hodgkins, G.J. McCabe, and D.W. Wolock, **National streamflow trends and development of hydrologic change indicators for surface-water resources of the United States**. American Geophysical Union, San Francisco, California, December, 2011
200. McCabe, G.J., and D.M. Wolock, **Independent Effects of Temperature and Precipitation on Modeled Runoff in the Conterminous U.S.** American Geophysical Union, San Francisco, California, December, 2011. (PRESENTED)
201. McCabe, G.J., and D.M. Wolock, **Independent Effects of Temperature and Precipitation on Modeled Runoff in the Conterminous U.S.** Association of American Geographers, New York, New York, February, 2012. (PRESENTED)

### c. RENDERING SCIENTIFIC JUDGEMENT:

**Associate Editor** for the *Journal of Hydrologic Engineering*, American Society of Civil Engineers, 1996-2002.

**Manuscript referee** for Science, Water Resources Research, Journal of the American Water Resources Association, Hydrological Processes, Journal of Hydrology, Geophysical Research Letters, Climate Research, Journal of Climate, Climatic Change, Advances in Water Resources, Bulletin of the American Meteorological Society, Texas Journal of Science, Intergovernmental Panel on Climate Change, Physical Geography, Professional Geographer, Journal of Hydrologic Engineering, Journal of Hydrometeorology, Weather and Forecasting, Ecology, Environmental Hazards, Global Environmental Change, Atmospheric Environment, Hydrology Research, and USGS publications. (*received 2009 Editor's Citation for Excellence in Refereeing for Geophysical Research Letters, American Geophysical Union*)

**Research proposal referee** for the National Oceanic and Atmospheric Administration, the U.S. Geological Survey, the Southeastern Regional Climate Center, the Southern Regional Climate Center, and the Western



Regional Climate Center.

**RGE peer panels**, Surface Water Hydrology and Geomorphology and Sediment Transport, 1997, 2000, 2001 (panel chair), 2003 (panel chair)

**Assistant Research Advisor**, Surface Water Discipline, 2000 through 2002.

**Research Advisor**, Surface Water Discipline, 2003 through 2005.

**USGS Global Change Science Proposal Review Panel**, USGS Expanded Research Opportunities in Global Change Science-2008, February-March, 2008.

#### **d. LECTURESHIPS AND OTHER ACADEMIC SERVICE:**

**Seminars at Universities:** (some of these presentations also may be listed in section 14b)

**University of Delaware**, Development of Objective Temporal and Spatial Synoptic Indices, August, 1984. **(INVITED)**

**Louisiana State University**, Application of Synoptic Weather Types in the Analysis of Evaporation in Southern Louisiana, August, 1986. **(INVITED)**

**Rutgers University**, Use of Synoptic Weather Types to Develop a Regional Climate Model, March, 1989. **(INVITED)**

**Colgate University**, Effects of Climatic Change on the Water Resources of the Delaware River Basin, February, 1990. **(INVITED)**

**University of Delaware**, Atmospheric Circulation, Sea-Surface Temperatures, and Mass Balance of South Cascade Glacier, April, 1995. **(INVITED)**

**Brigham Young University**, Atmospheric Circulation and the Mass Balance of South Cascade Glacier, Washington, January, 1996. **(INVITED)**

**Louisiana State University**, Pacific Ocean Climate and the Hydroclimate of the United States, November, 1997. **(INVITED)**

**University of Colorado**, Modulating Effects of the Pacific Decadal Oscillation on ENSO Teleconnections with Winter Precipitation in the Western United States, April 2000. **(INVITED)**

**Metropolitan State College of Denver**, Pacific Ocean Teleconnections with Western U.S. Hydroclimate, March 2001 **(INVITED)**

**Louisiana State University**, Decadal Variability in the Strength of ENSO Teleconnections With Winter Precipitation in the Western United States, April 2001 **(INVITED)**

**Louisiana State University**, A Possible Connection Between the 1878 Yellow Fever Epidemic in the Southern United States and the 1877-78 El Nino Episode, April 2001 **(INVITED)**

**University of Denver**, Pacific Ocean Teleconnections With the Hydroclimate of the United States, May 2001 **(INVITED)**

**Metropolitan State College of Denver**, Lectures on climate variability and change, 1999-present. **(INVITED)**

**University of Colorado**, Large-Scale Climate Dynamics and Hydro-Climate Variability in the United States, Center for Science and Technology Policy Research, University of Colorado, September, 2003 **(INVITED)**.

**University of Arizona**, Hydroclimatology of Drought and the Future of Water Resources in the Western United States, Institute for the Study of Planet Earth, University of Arizona, Tucson, Arizona, February, 2004. **(INVITED)**.

**University of Colorado**, Hydroclimatology of the Western United States, Center for Science and Technology Policy Research, University of Colorado, March, 2004 **(INVITED)**.

**University of Colorado**, Associations of Multi-Decadal Sea-Surface Temperature Variability with U.S. Hydroclimate, Hydrologic Sciences and Water Resources Engineering seminar, University of Colorado, Boulder, Colorado, April, 2006. **(INVITED)**

**Lehigh University**, Patterns, Sources, and Impacts of Decadal-to-Multidecadal Climate Variability, Department of Earth and Environmental Sciences, Lehigh University, Bethlehem, Pennsylvania, October, 2006. **(INVITED)**

**University of Colorado**, Sustainability of water supply in the Colorado River basin, Department of Geography, University of Colorado, Boulder, Colorado, February, 2009. **(INVITED)**

**University of Colorado**, Warming may create substantial water supply shortages in the Colorado River basin, Engineering Center, University of Colorado, Boulder, Colorado, November, 2009. **(INVITED)**

**USGS Seminars:** (some of these presentations also may be listed in section 14b)

Choosing and Applying Scenarios of Climatic Change: **NOAA/USGS Hydrologic Research Meeting**, Reston, Virginia, November, 1989. **(INVITED)**

Climate Change and Water Resources in the Delaware River Basin: **USGS Chief Hydrologist's Research Seminar and Briefing to the Director**, Reston, Virginia, October, 1990. **(INVITED)**

Uncertainty in Predicting the Hydrologic Effects of Climatic Change: **USGS Seminar**, Denver, Colorado, January, 1991. **(INVITED)**

Current Hydroclimatological Research, **USGS Seminar**, U.S. Geological Survey National Training Center, Denver, Colorado, February, 1993.

Effects of Climate, Topography, and Soils on Streamflow Generation, **USGS Seminar**, U.S. Geological

Survey National Training Center, Denver Colorado, March, 1995.

Applications of Synoptic Climatological Methods in Hydrologic Research, **USGS National Research Program Lecture Series**, 1996-97, lectures given at the New Mexico, Puerto Rico, Mississippi, and Ohio Water Science Centers, and at the Cascades Volcano Observatory. **(INVITED)**

Hydroclimatology of the 2002 Drought, **Central Region Executive Leadership Team**, U.S. Geological Survey, Denver, Colorado, June, 2002. **(INVITED)**

USGS Hydroclimatic Research, **seminar for visiting Chinese delegation**, Denver Federal Center, Denver, Colorado, December, 2003. **(INVITED)**

Ocean Influences on Multi-Decadal Drought, **National Research Program Seminar**, U.S. Geological Survey, Denver, Colorado, April, 2004. **(INVITED)**

Hydroclimatology of Drought in the Western United States, **Central Region Executive Leadership Team**, U.S. Geological Survey, Denver, Colorado, June, 2004. **(INVITED)**

Drought: Historic Context, Drought, **Climate Variability, and Water Supply Workshop**, Colorado Water Science Center, Denver, Colorado, January, 2005. **(INVITED)**

Climate Variability: Paleoclimatic and Historic Contexts, **Nebraska Water Science Center seminar**, Lincoln, Nebraska, February, 2005. **(INVITED)**

Climate Change and Global runoff, **Director's briefing**, U.S. Geological Survey, Denver, Colorado, March, 2007. **(INVITED)**

Global Sea-Surface Temperatures and North American Droughts and Pluvials, **National Research Program Seminar**, U.S. Geological Survey, Denver, Colorado, April, 2007. **(INVITED)**

North American Drought: Paleoclimatic and Historic Context, **Joint USGS/USACE/USBOR/NOAA workshop**, Washington, D.C., May, 2007. **(INVITED)**

**Hydrologic Effects of Climate Change in the Yukon River Basin**, seminar, Colorado Water Science Center, Denver, Colorado, January, 2008. **(INVITED)**

**Sensitivity of water supply in the Colorado River Basin to warming**, USGS seminar, Branch of Regional Research, Eastern Region, Reston, Virginia, June, 2008. **(INVITED)**

## **University Courses Taught:**

### **University of Memphis (1986-88)**

- Introduction to Meteorology (1000 level)
- Meteorology (4000/6000 level)
- Climatology (4000/6000 level)
- Computer Applications (4000/6000 level)
- Seminar in Climatology (7000 level)

**Rider College (1989)**

Geologic Landforms (1000 level)

**Delaware Valley College (1990-1991)**

Climatology (4000/6000 level)

Water Resources (4000/6000 level)

**Metropolitan State College of Denver (2000-present)**

Meteorology (1000 level)

Climatology (4000 level)

**University of Denver (2004-present)**

Water Resources Analysis (4000/6000 level)

Climatology (4000/6000 level)

Applied Climatology (4000/6000 level)

Meteorology (4000/6000) level

**Graduate Students Advised: (student names not shown per Federal government regulations)**

**University of Memphis**

adviser and member of MS committee, 1986-1988.

adviser and member of MS committee, 1986-1988.

**University of Delaware**

served as an outside adviser on MS thesis, Development of a Regional  
Synoptic Index for Environmental Analysis, 1993.

served as an outside adviser on MS thesis, Development of a Synoptic  
Classification of North American Atmospheric Circulation, 1994.

**University of Denver**

member of MS committee, 2009-2010

Effect of Spruce Beetle on Snow Accumulation in Engelmann Spruce Stand, Rio Grande  
National Forest, Colorado

### **University Committees:**

Committee on computer use, Department of Geography and Planning, **University of Memphis**, August 1986 to August 1988.

Academic Senate, **University of Memphis**, May 1987 to May 1988.

Coordinator of introductory weather and climate courses, Department of Geography and Planning, **University of Memphis**, August 1987 to August 1988.

Committee on policies for introductory physical geography courses, Department of Geography and Planning, **University of Memphis**, August 1987 to August 1988.

Committee on environmental and Earth science courses, Department of Geography and Planning, **University of Memphis**, August 1987 to August 1988.

Academic Senate committee on research policies, **University of Memphis**, August 1987 to August 1988.

Graduate program evaluation committee, Department of Geography and Planning, **University of Memphis**, August 1987 to August 1988.

Committee to develop an undergraduate concentration in climatology, Department of Geography and Planning, **University of Memphis**, January 1987 to August 1988.

### **e. TECHNICAL TRAINING PROVIDED:**

**Development of Climatic Change Scenarios for Water Resource Sensitivity Studies**, Techniques for Hydrologic Investigations for International Participants, U.S. Geological Survey National Training Center, Denver, Colorado, July, 1992.

**Development and Use of Stochastic Models for Climate Change Studies**, USGS/NSF University Faculty Enhancement Workshop, U.S. Geological Survey National Training Center, Denver, Colorado, July, 1992.

**Development of a Stochastic Precipitation Model**, Public Works Research Institute of Japan, Tskuba, Japan. March, 1993.

**Precipitation-Runoff Modeling**, seminar, Middle East Peace Tour, Colorado River Basin Study, U.S. Geological Survey National Training Center, Denver, Colorado, July, 1993.

**Precipitation-Runoff Modeling Project**, USGS/NSF University Faculty Enhancement Workshop, U.S. Geological Survey National Training Center, Denver, Colorado, July, 1993.

**Multivariate Statistics Class**, U.S. Geological Survey National Training Center, Denver, Colorado, November

2006; March 2009

**f. SPECIAL ASSIGNMENTS:**

USGS climate change scenario development committee, 1991-1994.

USGS/Japan conference report drafting committee, February, 1992.

Organizing committee for the Second USGS/Japan Workshop on the Effects of Global Climate Change on Water Resources.

Member of USGS delegations to the first, second and third USGS/Japan Workshops on the Effects of Global Climate Change on Water Resources.

U.S. Geological Survey representative at the interagency meeting on the development of climate-change scenarios, Atlanta, Georgia, May, 1991.

USGS representative at the Interagency/Electric Power Research Institute Retreat on the Effects of Environmental Change on the Hydrologic Cycle at the River Basin Scale, December, 1992.

Served as an advisor, writer, and coordinator for the annual and seasonal Hydrologic Conditions Summaries for the National Water Summary, 1989-1996.

Advisor to the U.S. Geological Survey's National Water Summary Wetlands Project, Denver, Colorado, 1992.

U.S. Geological Survey committee on Hydroclimatological Research, 1996.

Research Grade Evaluation (RGE) peer panel for Surface Water/Geomorphology and Sediment Transport Disciplines, 1997.

Member of editorial committee for the white paper on Hydrologic Effects of Climate Change requested by the White House, 1997.

Member of the Ad Hoc Employee Development Committee, 1998.

Member of the USGS Analysis Team for the U.S. National Assessment of the Potential Consequences of Climate Change, 1998-1999.

Research Grade Evaluation (RGE) peer panel for Surface Water/Geomorphology and Sediment Transport Disciplines, 2000.

USGS representative to the National Research Council Workshop on Predictability and Limits-of- Prediction for Hydrologic Sciences, Boulder, Colorado, September 21-22, 2000.

Chair, Research Grade Evaluation (RGE) peer panel for Surface Water/Geomorphology and Sediment Transport Disciplines, 2001.

Assistant Research Advisor, Surface Water Discipline, 2000-2002.

Research Advisor, Surface Water Discipline, 2003-2005.

Chair, Research Grade Evaluation (RGE) peer panel for Surface Water/Geomorphology and Sediment Transport Disciplines, 2003.

Chair, Water 2025 workshop breakout session on climate variability, Denver, Colorado, November, 2003.

Mountain Climate Working Group - Paleoclimate and Resource Management (2005-present).

World Meteorological Organization (WMO) Commission for Hydrology (2005-present) .

U.S. Geological Survey representative at the U.S. Geological Survey/Fish and Wildlife Service, Future Challenges Workshop, Denver, Colorado, May, 2005.

Proposal Review Panel, USGS Expanded Research Opportunities in Global Change Science-2008, February-March, 2008.

NRP, BRR-CR representative to Water Smart planning meeting, September, 2010.

USGS representative on EPA climatic indicators team, August 2010 to present.

Strategic Science Planning Team for Water, October 2010 to present.

Writing team for the WaterSMART Colorado River Basin Focus Area Study work-plan, January 2011 to present.

**invited participant**, NOAA workshop on climate variability and change, Boulder Colorado, September, 2011.

**invited speaker**, NOAA workshop on trends and causes of observed changes in heat waves, cold waves, floods, and drought, Climate Science Working Group of the U.S. Climate Assessment, November, 2011.

Member of the Powell Center Science Advisory Board, USGS Fort Collins Science Center, Fort Collins, Colorado, September 2011to present.

#### **g. OTHER TECHNICAL ACTIVITIES:**

At the request of the Chief Hydrologist, I helped write and edit a white paper on climate change and water resources prepared for the White House Office of Science and Technology Policy (1997).

Internet-served hydrologic model - with Steve Markstrom (USGS, Denver) I helped develop a water-balance model that can be run interactively on the internet using the user's data files. This project required the application of new computer technology to make hydrologic models widely available for use. The model was one of the first such models that could be run directly from the internet and the technology allowed the reading and writing of data files from the user's computer. The procedures used to develop this web-based model provided a template for the distribution of more complex hydrologic and statistical models. The advantages of this approach is that only one version of the model needs to be maintained (versus a number of versions for various operating systems), the model can be accessed by anyone that can connect to the internet, and users can read and write files to and from their own computer. A paper describing this approach was published in *Computers and Geosciences*. There was a lot of interest in this modeling distribution method. The project eventually led to the development of a Graphical-User Interface driven version of the water balance model that has been served from the internet for many years.

U.S. National Assessment of the Hydrologic Effects of Climate Change - I and five other USGS scientists were asked by the Chief Scientist for Research to serve on the analysis team for the U.S. National Assessment of the Hydrologic Effects of Climate Change. As part of this project Dave Wolock (USGS, Kansas) and I examined the effects of climate change on annual runoff in the conterminous U.S. using a water-balance approach (Wolock and McCabe, 1999). In addition to the runoff analyses, Dave Wolock and I examined the effects of climate change on snowpack in the western United States (U.S.) (McCabe and Wolock, 1999). The results from these papers were included in the final report published by the U.S. National Assessment.

World Meteorological Organization (WMO) Commission for Hydrology (2005-present) - serving on an international committee to analyze variability and trends in global hydroclimate data.

#### **15. TECHNOLOGY AND INFORMATION TRANSFER:**

USGS representative at the 1998 EPA workshop on effects of climate change in the southwestern United States.

Judge for Student Paper Competition, American Geophysical Union Hydrology Days, Fort Collins, Colorado, April, 1996.

Developed (in collaboration with Dan Cayan, USGS and Scripps Institution of Oceanography) a data set of April 1 snowpack accumulations for the western United States. This data set has been shared with USGS and university researchers. Recently, the data set was used and expanded by researchers at INSTARR at the University of Colorado.

With Dave Wolock (Kansas Water Science Center) developed extensive topographic, soils, climatic, and hydrologic data sets. These data sets include temperature, precipitation (characterized as monthly statistics of daily storm intensity, storm duration, and interstorm period), topography, the topographic index  $\ln(a/\tan B)$  used



in TOPMODEL, and soils data that we have gridded for 5 kilometer by 5 kilometer grids for the conterminous United States. These data sets are being used in NAWQA studies as well as global change studies. These data sets have been shared with other USGS scientists and with university researchers.

With Dave Wolock (Kansas Water Science Center) and Harry Lins (Office of Surface Water) I helped develop the **prototype USGS daily streamflow conditions web page**. This page provides current streamflow data in the context of historical values. It also provides current and historical daily values of streamflow via an interactive map. This web page provided the first national view of current streamflow conditions to the public. Since its development this page has been one of the most widely used USGS web pages (see <http://water.usgs.gov/waterwatch/>).

Developed a web page to distribute climate data and statistics for use by scientists working on the Amphibian Research and Monitoring Initiative.

Presentation of drought research at the USGS open house in Fort Collins, August 23, 2002.

Interviewed by *Science News* on the topic "**Long Dry Spells: Lengthy Droughts Tied to Long-Lived La Ninas**". (*Science News* 162:85-86, August 2002).

Numerous newspaper and radio interviews on drought in the U.S. (2004-present)

Radio interview, **Oceans and Drought**, Earth and Sky Radio Series, May, 2004.

FOX national news interview on drought, July 2005.

Participated in a USGS Podcast, **Drought: the Long, Slow Natural Hazard (Part 1)**, U.S. Geological Survey Podcast. (host: David Hebert), [www.usgs.gov/corecast](http://www.usgs.gov/corecast), episode 33, March, 2008.

Participated in a documentary for the *National Geographic Channel*, **What Killed the Aztecs**, participation in April, 2008, documentary released in October 2008.

**Congressional briefing** on effects of warming on water supply of the Colorado River Basin, June, 2008.

U.S. Geological Survey, National Research Program, BRR-CR representative to **Water Smart planning meeting**, September, 2010.

**Strategic Science Planning Team for Water**, October 2010 to present (at the request of the Director, USGS)

## 16. INVENTIONS, PATENTS HELD:

none

## 17. HONORS, AWARDS, RECOGNITION:

Graduated cum laude, University of Delaware, 1980

Graduate fellowship at the University of Delaware, 1981

Elected to Sigma Xi, 1987

Outstanding Performance Rating and Award, 1989

Research Award for Foreign Specialists, Public Works Research Institute of Japan, 1993 - I visited Japan and worked with scientists there to get a stochastic precipitation model running for application in their climate-change research program.

Outstanding Performance Rating. 1996

USGS Star Award, 1999, for development of the prototype of the National Hydrologic Conditions web page

Superior Service Award, 2003

2009 Editor's Citation for Excellence in Refereeing for Geophysical Research Letters, American Geophysical Union

Meritorious Service Award, 2011

USGS Star Award, 2011, for water balance modeling work for Alabama Water Science Center

## 18. BIBLIOGRAPHY:

### a. Published Reports: (36 of the following papers were invited)

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2. McCabe, G.J., and Jackson, A., 1984. Synoptic weather patterns associated with the 1982-1983 Louisiana floods, in Muller, R.A. and Faiers, G.E., eds., **Climatic Perspective of the Louisiana Floods, 1982-1983**, Studies in Geography and Anthropology: Louisiana State University, Baton Rouge, Louisiana, p. 5-18.
3. Thompson, R.C., McCabe, G.J., McLaughlin, J.D., Muller, R.A., and Moreau, M., 1985. Annual climatic summary: **Louisiana agricultural experiment stations 1984: Climate Report 84-1**, Louisiana State University Agricultural Center, Baton Rouge, Louisiana, 35 p. (I performed the data analysis and served as an editor.)
4. McCabe, G.J., McLaughlin, J.D., and Muller, R.A., 1985. Thornthwaite continuous monthly water budget: a program in BASIC for microcomputers: **Climate Paper 85-1, Louisiana Office of State Climatology**, Department of Geography and Anthropology, Louisiana State University, Baton Rouge, Louisiana, 17 p.

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6. McCabe, G.J., and Muller, R.A., 1985. A comparison of synoptic weather type indices: **A Report for the National Oceanic and Atmospheric Administration**: Louisiana Office of State Climatology, Department of Geography and Anthropology, Louisiana State University, Baton Rouge, Louisiana, 22 p.
  
7. McCabe, G.J., McLaughlin, J.D., and Muller, R.A., 1985. Thornthwaite daily water budget: a program in BASIC for microcomputers: **Climate Paper 85-4, Louisiana office of State Climatology**, Department of Geography and Anthropology, Louisiana State University, Baton Rouge, Louisiana, 22 p.
  
8. Bengtson, R.L., Fouss, J.L., and McCabe, G.J., 1985. Effects of evapotranspiration on modeling in southern Louisiana: **Proceedings, American Society of Agricultural Engineers**, Paper No. 85- 2516, 10 p. (I performed the comparisons of potential evapotranspiration models.)
  
9. McCabe, G.J., 1986. Application of synoptic weather types in the analysis of evaporation in southern Louisiana: **doctoral dissertation**, Department of Geography and Anthropology, Louisiana State University, Baton Rouge, Louisiana, 153 p.
  
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11. McCabe, G.J., and Muller, R.A., 1987. Synoptic weather types: an index of evaporation: **Physical Geography**, v. 8, p. 99-112.
  
12. McCabe, G.J., 1987. Long term temperature and precipitation trends for Memphis, Tennessee, 1872- 1985: **Journal of the Tennessee Academy of Science**, v. 62, n 4, p. 95-96.
  
13. Kung, H., and McCabe, G.J., 1988. An application of water budget to the study of urban hydrology in the Knoxville area: **Journal of Science and Technology Translation** (Wuhan, China), v. 54, n. 2, 81-89. (I performed data analyses, produced data summaries and edited the version that was finally published.)
  
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18. Wolock, D.M., Ayers, M.A., Hay, L.E., and McCabe, G.J., 1989. Prediction of the effects of climate change on watershed runoff in the Delaware River Basin: **Proceedings of the American Society of Civil Engineers**, p. 673-678. (I contributed ideas and served as editor.) (INVITED)
  
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25. McCabe, G.J., 1990. Physical Geography by Ralph C. Scott: **The Pennsylvania Geographer**, v. 28, n. 1, p. 51-52. (INVITED)
  
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28. Ayers, M.A., Tasker, G.D., Wolock, D.M., McCabe, G.J., and Hay, L.E., 1990. Simulated effects of climatic change on runoff and drought in the Delaware River Basin: Supplying Water and Saving the Environment for 6 Billion People, **Proceedings of the American Society of Civil Engineers**, p. 31-37. (I helped develop the water balance model and performed water balance sensitivity analyses, contributed sections of the text, and served as an editor.) (INVITED)
  
29. McCabe, G.J. and Ayers, M.A., 1990. Reply to a discussion by D.L. Verbyla of hydrologic effects of climate change in the Delaware River Basin: **Water Resources Bulletin**, v. 26, n. 5, p. 833-834.

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42. Hay, L.E., McCabe, G.J., Wolock, D.M., and Ayers, M.A., 1992. Use of weather-type analysis to disaggregate general circulation model predictions: **Journal of Geophysical Research**, v. 97, p. 2781-2790. (I researched and developed the weather types and helped research the use of weather types to apply general circulation model predictions of precipitation to watersheds.)
  
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the research, wrote large sections of text, and served as an editor.)

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## 19. PUBLICATIONS:

**Legates, D.R. and G.J. McCabe, 1999. Evaluating the use of “goodness-of-fit” measures in hydrologic and hydroclimatic model validation. Water Resources Research , 35:233-241.**

**Background:** Correlation and correlation-based measures ( e.g., the coefficient of determination) have been widely used to evaluate the "goodness-of-fit" of hydrologic and hydroclimatic models. These measures are over sensitive to extreme values (outliers) and are insensitive to additive and proportional differences between model predictions and observations. Because of these limitations, correlation-based measures can indicate that a model is a good predictor, even when it is not.

**Role:** I performed the analyses and contributed to the planning of the research approach. My co-author and I contributed equally to the writing of the journal paper.

**Results:** In this paper useful alternative goodness-of-fit or relative error measures (including the coefficient of efficiency and the index of agreement) that overcome many of the limitations of correlation-based measures are discussed. It is concluded that correlation and correlation-based measures alone should not be used to assess the goodness-of-fit of a hydrologic or hydroclimatic model and that additional evaluation measures (such as summary statistics and absolute error measures) should supplement model evaluation tools.

**Impact:** This paper provided a detailed evaluation of goodness-of-fit measures for validation of hydrologic and hydroclimatic models. The paper has been cited in over 886 other papers and is one of the most cited papers published in *Water Resources Research*.

**McCabe, G.J., M.A. Palecki, and J.L. Betancourt, 2004, Pacific and Atlantic Ocean Influences on Multi-Decadal Drought Frequency in the Conterminous United States. Proceedings of the National Academy of Sciences, v. 101, p. 4136-4141.**

**Background:** Though long considered implausible, there is growing promise for probabilistic, climatic forecasts one or two decades into the future based on quasi-periodic variations in sea surface temperatures (SSTs), salinities, and dynamic, ocean topographies. Such long-term forecasts could help water managers plan for persistent drought across the conterminous US. The urgency for such planning became evident when much of the US was gripped by drought in 1996 and again in 1999-2003, evoking images of the dry 1930s and 1950s. Analyses and forecasting of US precipitation have focused primarily on the Pacific Ocean, and more specifically on oceanic indices such as those used to track the El Niño Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO). Much of the long-term predictability in North American climate, however, may actually reside in both observed and modeled multi-decadal (50-80 years) variations in North Atlantic SSTs. Modeling studies indicate that multidecadal variability in North Atlantic climate is dominated by a single mode of SST variability (the Atlantic Multidecadal Oscillation (AMO)). In this study we decomposed drought frequency in the conterminous US into its primary modes of variability without a priori consideration of climate forcing factors. These modes were then related both spatially and temporally to the PDO and AMO to determine the relative influence of the SST patterns tracked by these indices on the probability of drought. Consideration of the potential role of Northern Hemisphere temperature or some other unidirectional trend also proved necessary to understand the variance in drought frequency.

**Role:** I conceived the idea for the study, compiled the data sets, and performed the analyses. I developed the research plan and my co-authors and I contributed equally to the final journal paper.

**Results:** More than half (52%) of the spatial and temporal variance in multi-decadal drought frequency over the conterminous United States (US) is attributable to variability of SSTs in the North Pacific (the PDO) and North Atlantic (the AMO) Oceans. These results support previous research that has indicated the existence of a relation between these climate indices and drought variability in the US. The inclusion of the PDO, AMO, and a trending geophysical indicator like Northern Hemisphere temperature, appears to be crucial in generating

multiple regression equations that can accurately simulate the historical 20-year patterns of drought frequency. This research indicates that persistence of the current positive AMO state may lead to continuing above normal frequencies of US drought in the near future, with the pattern of drought modulated by the sign of the PDO. Additionally, much of the long-term predictability of drought frequency may reside in the multi-decadal behavior of the North Atlantic Ocean. This research suggests that on decadal to multi-decadal time scales the influence of North Atlantic Ocean variability on US hydroclimate may be as important as the influence of Pacific Ocean variability.

**Impact:** Increased understanding of decadal to multi-decadal regimes has important implications for improvement of climatic and hydrologic forecasts. This paper received a great deal of attention and initiated a great deal of discussion among climate scientists. My co-authors and I presented over 60 invited talks on the paper topic and were interviewed by many media outlets (i.e. newspapers, radio, television etc.). This work also was referenced in an article that appeared in *Time* magazine, was the basis of an invitation to participate in a USGS podcast, was the subject of a National FOX NEWS story, and was part of a documentary for the *National Geographic Channel*. This paper has been cited by at least 258 other papers.

**McCabe, G.J., and D.M. Wolock, 2007. Warming may create substantial water supply shortages in the Colorado River. Geophysical Research Letters, 34, L22708, doi:10.1029/2007GL031764.**

**Background:** The high demand for water, the recent multiyear drought (1999-2007), and projections of global warming have raised questions about the long-term sustainability of water supply in the southwestern United States. In this study, the potential effects of specific levels of atmospheric warming on water-year streamflow in the Colorado River basin are evaluated using a water-balance model, and the results are analyzed within the context of a multi-century tree-ring reconstruction (1490-1998) of streamflow for the basin.

**Role:** Although I conceived the idea, my co-author and I contributed equally to the research plan. I programmed the water balance and reservoir models, compiled the data sets needed for the study, and performed the modeling experiments. My co-author and I both contributed equally to the writing of the journal paper.

**Results:** The results indicate that if future warming occurs in the basin and is not accompanied by increased precipitation, then the basin is likely to experience periods of water supply shortages more severe than those inferred from the long-term historical tree-ring reconstruction. Furthermore, the modeling results suggest that future warming would increase the likelihood of failure to meet the water allocation requirements of the Colorado River Compact.

**Impact:** This paper was mentioned in a “Search and Discovery” article in *Physics Today* (April 2008) on climate change, also resulted in a press conference with USGS Director Mark Myers in April 2008 and was the focus of a congressional briefing in June 2008. This paper also was featured in a story published in an issue of *Scientific American* (December 9, 2008) and both the Secretary of Interior and the Assistant Secretary of Interior have requested information from this research for talks they presented.